NASA SP-7037(242)

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 242)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in July 1989 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

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INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 466 reports, journal articles and other documents originally announced in July 1989 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cummulative index will be published.

Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

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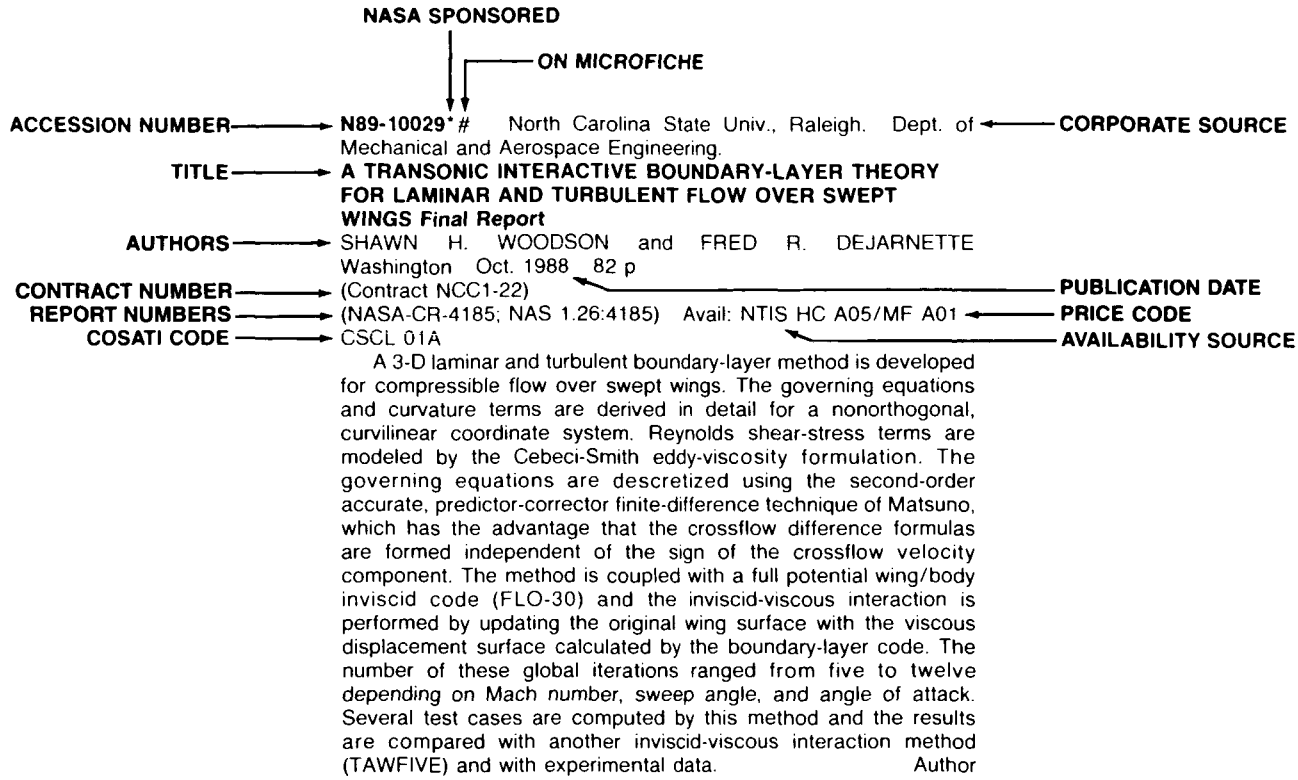
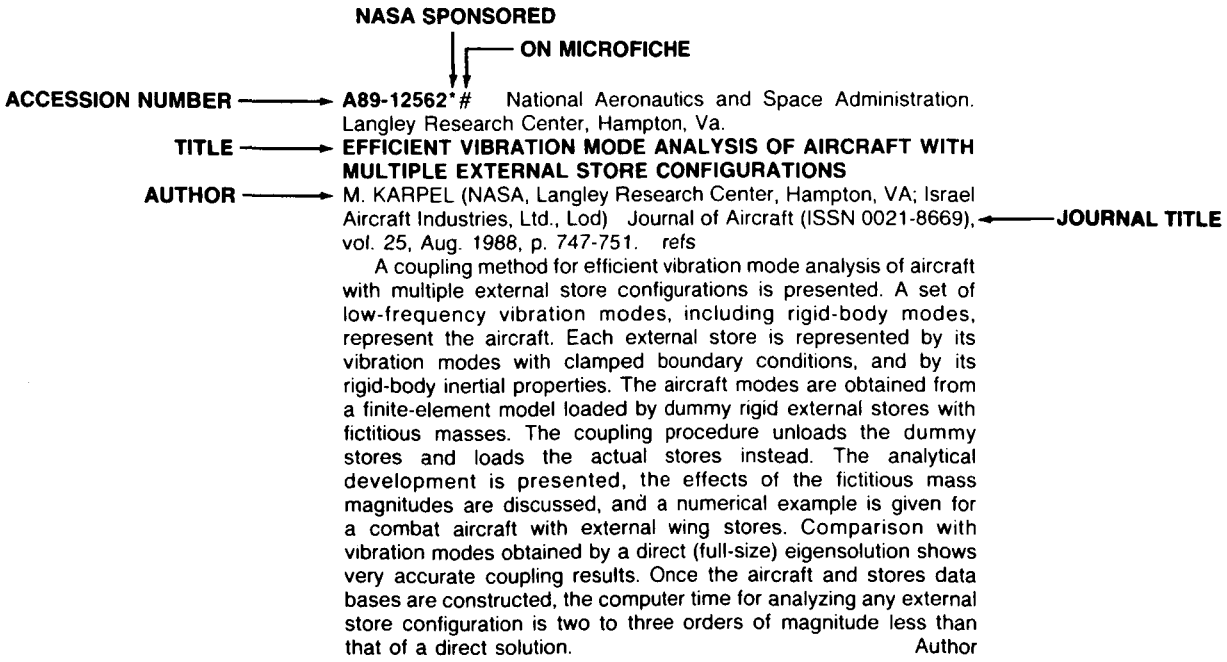
TYPICAL REPORT CITATION AND ABSTRACT



TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 242)

AUGUST 1989

01

AERONAUTICS (GENERAL)

A89-32775
DFVLR, ANNUAL REPORT 1987 [DFVLR, JAHRESBERICHT 1987]
Cologne, DFVLR, 1988, 100 p. In German. No individual items are abstracted in this volume.

The activities of the FRG aerospace research organization DFVLR in aeronautics, astronautics, and energy technology during 1987 are surveyed. Topics addressed include the computer-based ATC planning and decision tool COMPAS, wind-tunnel tests on a delta wing as part of the International Vortex Flow Experiment, mesoscale remote sensing of the atmosphere for meteorological applications, wind-tunnel testing of reentry bodies in the hypersonic regime, renewable energy sources, and the organizational and financial status of DFVLR. Extensive photographs, drawings, and diagrams are provided, and an English summary is given for each section. T.K.

A89-32982
MATHEMATICAL RESEARCH AT THE AERONAUTICAL RESEARCH LABORATORIES 1939-1960
D. G. HURLEY (Western Australia, University, Nedlands, Australia) Australian Mathematical Society, Journal, Series B - Applied Mathematics (ISSN 0334-2700), vol. 30, April 1989, p. 389-413. refs

A review of mathematical studies undertaken to support experimental work at the Australian Aeronautical Research Laboratories during the first 20 years of their operation is presented. Topics addressed include wind-tunnel design and corrections, wood in aircraft construction, boundary-layer flow and turbulence, heat transfer at low Reynolds numbers, stalling of thin wings, transonic airfoils, supersonics, vibrations, fatigue, and mathematical methods. Diagrams, graphs, and typical flow visualizations are provided. T.K.

A89-33555
THE U.S. NAVY UNMANNED AIR VEHICLE PROGRAM
EDWARD E. DAVIS (U.S. Navy, Naval Air Systems Command, Washington, DC) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 1.1-1.11.

The U.S. Navy's progress to date in RPV development is discussed with a view to remaining problems in at-sea and shore operations and the Navy's role as part of the DoD Joint Service RPV baseline design-development program, which is to result in competitive procurement in 1990. Attention is given to the system components of the already-operational Pioneer RPV, the installation of Pioneer RPVs aboard battleships, the status of the Amber high-altitude/long-endurance RPV, the design requirements formulated to date for the baseline midrange RPV concept, and the NATO ships-compatible Small Ship RPV development effort. O.C.

A89-33559
FALCONET TARGET RPV OPERATIONS
SIMON F. DICKINSON (Flight Refuelling, Ltd., Wimborne, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 9.1-9.11.

Falconet is a British target-practice RPV employed at the Royal Artillery Range in the Hebrides, Scotland. The air vehicle is a conventional low-wing monoplane with a single podded-installation turbojet beneath the fuselage. The ground control system for Falconet has been designed to integrate the operation of the target with existing tracking radars of the Royal Artillery Range. Both carousel and zero-length (rocket-assisted) takeoff systems are available. Controllers that may be used encompass those for the launch area, recovery area, visually-guided flight and radar-guided flight. The Falconet air vehicle's structural components are of modular type for ease of maintenance and repair. O.C.

A89-33560
CIVILIAN RPVS - EYE IN THE SKY OR PIE IN THE SKY?
A. M. CUDMORE, K. S. GIBSON, D. M. LUMBROSO, A. J. STOCKS, and I. D. TINSON (Southampton, University, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 11.1-11.10.

A feasibility study has been conducted for a civilian-applications observational sensor-platform RPV, designated the Southampton University Remotely Piloted Airborne Surveillance System (SURPASS), operating beyond visual range with a real-time video camera. This RPV for UK use would be designed to ensure that the complex interactions inherent in any remote system are taken fully into account. The SURPASS flight control system would be similar to those of military RPVs, using ground radar tracking of the vehicle and a combination of autopilot and ground-piloting on the basis of telemetered sensor data. O.C.

A89-34448
GENERAL AVIATION
MALCOLM L. RITCHIE (Ritchie, Inc., Dayton, OH) IN: Human factors in aviation. San Diego, CA, Academic Press, Inc., 1988, p. 561-589. refs

Human-factors analysis techniques are applied to characterize the general-aviation (GA) pilot, aircraft, and operational environment. The focus is on the nonprofessional end of the GA spectrum. Consideration is given to pilot skill level and skill maintenance, equipment costs, human performance in GA, the GA cockpit (instrument flight capabilities, controls, and displays), GA performance variables (manipulative skills, information acquisition and processing, decision processes, input processes, and emergency operations), systems management (propulsion, communication, and cruise), in-flight correction of malfunctions, navigation tasks, and ATC-related tasks. Possible improvements in GA avionics based on personal computers and smart data links are described. T.K.

A89-34450
AIR TRAFFIC CONTROL
V. DAVID HOPKIN (RAF, Institute of Aviation Medicine, Farnborough, England) IN: Human factors in aviation. San Diego, CA, Academic Press, Inc., 1988, p. 639-663. refs

The application of human-factors (HF) analysis techniques to the ATC task, equipment, and operational environment is discussed in an introductory review. The evolution of HF research since the 1950s is briefly recalled; the typical ATC tasks are listed and characterized; the problems of workstation design are outlined; typical controller selection and training procedures are described; and particular attention is given to the factors leading to human error, the effects of workstation design on controller health, the problems of stress and boredom, the measurement of controller workload and performance, and the impact of automation. It is pointed out that many changes in ATC technology are neither motivated by HF concerns nor necessarily beneficial in the HF sense. T.K.

A89-34896#
FAST, IN-SITU REPAIR OF AIRCRAFT PANEL COMPONENTS
S. DEHM and D. WURZEL (DFVLR, Stuttgart, Federal Republic of Germany) (ICAS, Congress, 15th, London, England, Sept. 7-12, 1986, Proceedings. Volume 2, p. 836-843) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 476-481. Previously cited in issue 24, p. 3524, Accession no. A86-49066.

A89-35100
B-2 - THE END OF THE LONG ROAD TOWARD A 'STEALTH BOMBER' [B-2 - EL FINAL DEL LARGO CAMINO HACIA EL 'BOMBARDERO FURTIVO']
JOSE ANTONIO MARTINEZ CABEZA Ingenieria Aeronautica y Astronautica (ISSN 0020-1006), Feb. 1989, p. 13-25. In Spanish.

A development history is presented for the USAF B-2 'stealth bomber', with a view to competing strategic aircraft alternatives considered during the 1970s and the debt owed by the B-2's configuration designers to the experience gained by the Northrop 'flying wing' aircraft XB-35, and the YB-49 of the 1950s. The B-2 is noted to have been produced almost entirely via totally integrated CAD/CAM facilities requiring the investment of some $1 billion by the primary contractor. The proposed production run of 132 B-2 aircraft is estimated to cost $70 billion. The first B-2 to be completed was unveiled on November 22, 1988. O.C.

A89-35125
LIFE WITH THE OLDER AIRCRAFT
BILL SWEETMAN Interavia (ISSN 0020-5168), vol. 44, March 1989, p. 250-252, 254.

Maintenance costs for older airliners are 2-3 times higher than those for more recent types; these costs are expected to further increase as regulatory responses to recent fuselage fatigue- and corrosion-instigated accidents opt for more conservative assumptions about fatigue resistance in light Al-alloy structures subjected to thousands of pressurization/depressurization cycles. Attention is presently given to a tabulation of data concerning the number of aircraft, economic design service life objective, and number of aircraft that have operated beyond the 75-percent and 100-percent points of that service life objective, for B-707, B-720, B-727, B-737, and B-747 airliner types. O.C.

A89-35376
ONERA RESEARCH ON CIVIL AIRCRAFT [RECHERCHES DE L'ONERA SUR LES AVIONS CIVILS]
J.-P. MAREC (ONERA, Chatillon-sous-Bagneux, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 134, 1989, p. 3-17; Comments, p. 17, 18. In French. refs

Civil-aircraft research conducted at ONERA concerning airframes, propulsion, and safety is reviewed. Airframe studies are performed on drag reduction, aeroelasticity, flight mechanics, the buckling of composite structures, and the strength of aluminum-lithium alloys. Propulsion research discussed includes such topics as combustion, high-temperature turbine-blade fatigue, propfan engines, and propulsion/airframe integration. Safety regulations concerning lightning strikes and the effects of icing are also considered. R.R.

A89-35377
THE FUTURE OF THE CIVIL AVIATION INDUSTRY [LES ENJEUX DE LA CONSTRUCTION AERONAUTIQUE CIVILE]
G. DELALANDE (Direction Generale de l'Aviation Civile, Paris, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 134, 1989, p. 19-23. In French.

The future character of the civil aviation industry is predicted based on current market trends and recent technological advances. Areas of improvement for civil transport aircraft, regional transport aircraft, business aircraft, and helicopters are listed in order of priority. Technological advances considered include improved engine fuel consumption, improved modeling of engine aerodynamics, the development of advanced materials, and flight control systems. R.R.

A89-35378
CIVIL-TRANSPORT AIRCRAFT AT AEROSPATIALE [LES AVIONS DE TRANSPORT CIVIL A L'AEROSPATIALE]
C. TERRAZZONI (Aerospatiale, Division Avions, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 134, 1989, p. 24-31. In French.

The status and future of the Airbus and ATR civil aircraft programs are considered. Recent Airbus developments include an increased flight range and the ability to carry more passengers. Finite element calculations for studying linear and nonlinear phenomena and structural optimization problems are discussed. Other topics reviewed include the reduction of maintenance costs, performance improvements, the application of the propfan, and the development of supersonic and hypersonic vehicles. R.R.

A89-35379
BUSINESS AVIATION AND NEW TECHNOLOGIES [AVIATION D'AFFAIRES ET TECHNOLOGIES NOUVELLES]
J. MAESTRATI (Avions Marcel Dassault Breguet Aviation, Merignac, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 134, 1989, p. 32-34. In French.

New technologies for business aircraft are discussed, with special attention given to the application of laminar flow techniques. It is predicted that the maximization of laminar flow will result in a 15 percent increase in flight range. Wind tunnel and flight test results for laminar flow obtained with the Falcon 50 aircraft have confirmed theoretical predictions. The possibility of a supersonic business aircraft using extended laminarity and having a 7500-km flight radius is considered. R.R.

N89-20086*# National Aeronautics and Space Administration, Washington, DC.
PERFORMANCE AND TEST SECTION FLOW CHARACTERISTICS OF THE NATIONAL FULL-SCALE AERODYNAMICS COMPLEX 40- BY 80-FOOT WIND TUNNEL
PETER T. ZELL and KAREN FLACK Feb. 1989 81 p (NASA-TM-101065; A-89028; NAS 1.15:101065) Avail: NTIS HC A05/MF A01 CSCL 01A

Results from the performance and test section flow calibration of the 40-by 80-Foot Wind Tunnel are presented. A flow calibration test was conducted in May and June 1987. The goal of the flow calibration test was to determine detailed spatial variations in the 40-by 80-ft test section flow quality throughout the tunnel operational envelope. Data were collected for test section speeds up to 300 knots and for air exchange rates of 0, 5, and 10 percent. The tunnel performance was also calibrated during the detailed mapping of the test section flow field. Experimental results presented indicate that the flow quality in the test section, with the exception of temperature, is relatively insensitive to the level of dynamic pressure and the air exchange rate. The dynamic pressure variation in the test section is within + or - 0.5 deg at all test section velocities. Cross-stream temperature gradients in the test section caused by the air exchange system were documented, and a correction method was established. Streamwise static pressure variation on the centerline is about 1 percent of test section dynamic pressure over 30 ft of the test section length. Author

N89-20087# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
ENVIRONMENT-ASSISTED AEROSPACE FATIGUE PROBLEMS IN THE NETHERLANDS
R. J. H. WANHILL 2 Feb. 1988 24 p Presented at the Environmentally Assisted Fatigue Symposium, Sheffield, England, Apr. 1988
(NLR-MP-88004-U; ETN-89-94053) Avail: NTIS HC A03/MF A01

Corrosion and environment-assisted fatigue problems in aircraft, and the measures taken to alleviate them are reviewed. Landing gear, airframes, flying controls, propellers and rotor blades, and engines are discussed. ESA

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A89-33100#
ON A METHOD FOR SOLVING INTEGRAL EQUATIONS OF LIFTING-SURFACE THEORY FOR OSCILLATING HIGH-SPEED PROPELLERS
TERUO ICHIKAWA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 37, no. 420, 1989, p. 47-51. refs

A lifting-surface theory of oscillating high-speed propellers has been formulated earlier by the author in a form of integral equations. In this paper, a method for solution of these integral equations is proposed. An adjoint variational principle, equivalent to the integral equations for direct and reverse flows, as well as to the Kutta conditions in both the flows, is derived. It is shown that the generalized aerodynamic forces acting on the propeller blades will be computed advantageously by applying a Rayleigh-Ritz type method to the variational principle. Author

A89-33140
A STUDY OF THE ROTOR WAKE IN NAP-OF-THE-EARTH
CHENGJAN HE and ZHENG GAO (Nanjing Aeronautical Institute, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 1, July 1988, p. 71-78. refs

An investigation of the ground vortex, the most significant aerodynamic phenomenon in rotor aerodynamics during nap-of-the-earth flight, is carried out. Based on the analysis of the rotor wake near the ground, a theoretical method has been established which can be used for calculating the ground vortex, its longitudinal position, and its strength. The computational results are compared with available experimental data and found to be in good agreement. Author

A89-33142
A DIGITAL SIMULATION TECHNIQUE FOR DRYDEN ATMOSPHERIC TURBULENCE MODEL
ZHENYAN ZHAO, YELUN XIAO, and YIJIAN SHI (Beijing University of Aeronautics and Astronautics, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 1, July 1988, p. 87-97. refs

The Dryden model is usually used in studying the response of a flight vehicle to atmospheric turbulence. For a modern flight simulator, it is necessary to generate random winds (in the Dryden model or sometimes in others) with a digital computer. In this paper, a theoretically strict new method to meet this purpose is proposed. By this method, a three-dimensional atmospheric turbulence is obtained which contains three components of the wind velocity and three components of the wind-velocity gradient. The reliability of this method is checked by comparing the autocorrelation value obtained with the theoretical one. A numerical example has shown a satisfactory result. Author

A89-33249*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HOT GAS INGESTION TESTING OF AN ADVANCED STOVL CONCEPT IN THE NASA LEWIS 9- BY 15-FOOT LOW SPEED WIND TUNNEL WITH FLOW VISUALIZATION
ALBERT L. JOHNS (NASA, Lewis Research Center, Cleveland, OH), JOSEPH D. FLOOD, THOMAS W. STROCK, and KURT C. AMUEDO (McDonnell Aircraft Co., Saint Louis, MO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 26 p. Previously announced in STAR as N89-15078.
(AIAA PAPER 88-3025)

Advanced Short Takeoff/Vertical Landing (STOVL) aircraft capable of operating from remote sites, damaged runways, and small air capable ships are being pursued for deployment around the turn of the century. To achieve this goal, it is important that the technologies critical to this unique class of aircraft be developed. Recognizing this need, NASA Lewis Research Center, McDonnell Douglas Aircraft, and DARPA defined a cooperative program for testing in the NASA Lewis 9- by 15-foot Low Speed Wind Tunnel (LSWT) to establish a database for hot gas ingestion, one of the technologies critical to STOVL. Results from a test program are presented along with a discussion of the facility modifications allowing this type of testing at modal scale. These modifications to the tunnel include a novel ground plane, an elaborate model support which included 4 degrees of freedom, heated high pressure air for nozzle flow, a suction system exhaust for inlet flow, and tunnel sidewall modifications. Several flow visualization techniques were employed including water mist in the nozzle flows and tufts on the ground plane. Headwind (free-stream) velocity was varied from 8 to 23 knots. Author

A89-33383#
SINGLE AND MULTI-ELEMENT AIRFOILS IN AN ISOTROPIC TURBULENT OUTER FLOW
GEORGE D. CATALANO, C. MIKE FREMAUX (Louisiana State University, Baton Rouge), and ERIC B. ZIMMERMAN (U.S. Military Academy, West Point, NY) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 3.12 (5 p.). refs

It is shown that allowance should be made for the magnitude of the free-stream turbulent intensity in estimates of the lift and pitching moment coefficients for both single and multielement airfoils. At a given angle of attack, the lifting efficiency of the airfoil decreases with increasing turbulence intensity. A simple perturbation-analysis-based prediction model is developed which yields results in close agreement with the experimental data obtained. K.K.

A89-33385#
HELICOPTER ROTOR WAKE INVESTIGATION USING A LASER DOPPLER ANEMOMETRY TECHNIQUE
M. NSI MBA, D. FAVIER, C. MARESCA, and P. CRESPI (Institut de Mecanique des Fluides, Marseille, France) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 5.12 (7 p.). refs
(Contract DRET-87-095)

The aim of the present research is to provide an accurate description of the flowfield generated by helicopter rotors operating in hover and forward flight regimes. A two-dimensional laser velocimeter is implemented for instantaneous velocity measurements either in the wake or around the blades. The measurements performed near the blades then lead to determine the distribution of circulation along the blade span which is used to validate the predictions of rotor aerodynamics codes based on a free wake analysis calculation. Author

A89-33410
MEASUREMENTS OF MEAN-FLOW AND TURBULENCE CHARACTERISTICS IN A TURBOJET EXHAUST USING A LASER VELOCIMETER

HANS J. SCHAEFER (Saint-Louis, Institut Franco-Allemand de Recherches, France) IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. A13-1 to A13-9. refs

Mean-flow and turbulence characteristics have been measured in a high-temperature axisymmetric jet exhausting from an aero-engine and the effects of exit Mach number and temperature on the jet flow field were studied. A laser Doppler velocimeter was used to map the flow characteristics over a range of Mach numbers from 0.46 to 0.84. Radial distributions of the mean axial velocity and the rms of the corresponding fluctuations were obtained at different axial stations in the flow. The various distributions are found to collapse when plotted in appropriate coordinates and the collapsed data can be approximated by a universal profile. These experimental findings are in good agreement with previous measurements in isothermal jets. Author

A89-33423* Pennsylvania State Univ., University Park.
MEASUREMENTS OF A SUPERSONIC TURBULENT VORTEX
O. M. METWALLY and G. S. SETTLES (Pennsylvania State University, University Park) IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. A31-1 to A31-5. refs
(Contract NCA2-235)

Mean-flow measurements of a supersonic turbulent streamwise vortex are presented. This vortex was produced by the injection of a swirling flow along the centerline of a supersonic airstream at Mach 3. Directional Mach number distributions, obtained via a five-hole flow-angularity probe, reveal vortex characteristics similar to those of the incompressible case, even though rotational Mach numbers up to 0.8 were obtained. This work is the first step of a study of the supersonic vortex breakdown phenomenon. Author

A89-33424
INSTANTANEOUS PROFILES AND TURBULENCE STATISTICS OF SUPERSONIC FREE SHEAR LAYERS BY RAMAN EXCITATION + LASER-INDUCED ELECTRONIC FLUORESCENCE (RELIEF) VELOCITY TAGGING OF OXYGEN
R. B. MILES, J. J. CONNORS, E. C. MARKOVITZ, P. J. HOWARD, and G. J. ROTH (Princeton University, NJ) IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. A32-1 to A32-9. refs
(Contract AF-AFOSR-86-0191)

A new method of flow tagging based on the vibrational excitation of oxygen is applied to both supersonic and high-speed subsonic air flows to generate instantaneous velocity profiles and turbulence statistics across the free shear layer. By simultaneously tagging two lines, both transverse and streamwise velocity correlations are found. Rayleigh scattering can also be imaged, so this flow diagnostic technique has the capability of instantaneously recording density cross section and velocity profiles. Author

A89-33425
A COMPARISON OF THE TURBULENCE STRUCTURE OF SUBSONIC AND SUPERSONIC BOUNDARY LAYERS
A. J. SMITS, A. E. ALVING, R. W. SMITH, E. F. SPINA, E. M. FERNANDO (Princeton University, NJ) et al. IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. A33-1 to A33-10. refs
(Contract AF-AFOSR-88-0120)

A comparison of the turbulence structure of subsonic and supersonic boundary layers reveals that, despite broad similarities, significant differences exist. The length scales derived from space-time correlations indicate that the spanwise scales are almost identical but that the streamwise scales in the supersonic flow are about half the size of those in subsonic flow. The large-scale structures in the subsonic boundary layer appear to move slightly slower, and lean more toward the wall, than those observed in supersonic flows, and their shear stress content is distributed differently among the four quadrants. These observations should have a strong impact on deriving turbulence models for supersonic flows. Author

A89-33426
MEAN AND TURBULENT VELOCITY MEASUREMENTS OF SUPERSONIC MIXING LAYERS
S. G. GOEBEL, J. C. DUTTON, H. KRIER, and J. P. RENIE (Illinois, University, Urbana) IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. A34-1 to A34-10. refs
(Contract N00014-86-K-0434)

The behavior of supersonic mixing layers under three conditions has been examined by schlieren photography and laser Doppler velocimetry. It was found that higher levels of secondary freestream turbulence did not increase the peak turbulence intensity observed within the mixing layer, but slightly increased the growth rate. Higher levels of freestream turbulence also reduced the axial distance required for development of the mean velocity. At higher convective Mach numbers, the mixing layer growth rate was found to be smaller than that of an incompressible mixing layer at the same velocity and freestream density ratio. The increase in convective Mach number also caused a decrease in the turbulence intensity. Author

A89-33627#
COMPUTATION OF FLOW FIELDS FOR HYPERSONIC FLIGHT AT HIGH ALTITUDES
J. N. MOSS University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 46 p. refs

Data on the nature of the flow and aerodynamic characteristics of different reentry configurations under transitional-flow conditions are discussed. The important physical phenomena that occur under hypersonic low-density conditions are described. Direct simulation Monte Carlo calculations provide a means of establishing the limits on the valid application of continuum methods for hypersonic low-density flows. K.K.

A89-33634*# Stanford Univ., CA.
A NUMERICAL METHOD FOR PREDICTING HYPERSONIC FLOWFIELDS
ROBERT W. MACCORMACK and GRAHAM V. CANDLER (Stanford University, CA) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 8 p. Research supported by SDIO. refs
(Contract DAAI03-86-K-0139; NAGW-965; F33615-86-C-3015)

The flow about a body traveling at hypersonic speed is energetic enough to cause the atmospheric gases to chemically react and reach states in thermal nonequilibrium. The prediction of hypersonic flowfields requires a numerical method capable of solving the conservation equations of fluid flow, the chemical rate equations for specie formation and dissociation, and the transfer of energy relations between translational and vibrational temperature states. Because the number of equations to be solved is large, the numerical method should also be as efficient as possible. The proposed paper presents a fully implicit method that fully couples the solution of the fluid flow equations with the gas physics and chemistry relations. The method flux splits the inviscid flow terms, central differences of the viscous terms, preserves element conservation in the strong chemistry source terms, and solves the resulting block matrix equation by Gauss Seidel line relaxation. Author

A89-33637#
THE FLOW ON THE LEE-SIDE OF A DELTA WING AT MACH 7
M. LINDE (Flygtekniska Forsoksanstalten, Bromma, Sweden) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 14 p. refs

The structure of the flow field on the lee-side of a 70-deg delta wing with flat upper surface and rounded leading edge at M

= 7 and at a high angle of attack is studied. A conical five-hole pressure probe is used to study the flow. Surface oil flow is also used for the visualization of the flow close to the surface. K.K.

A89-33638#
EXPERIMENTAL METHODS FOR HYPERSONICS - CAPABILITIES AND LIMITATIONS
RICHARD D. NEUMANN University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 31 p. refs

Experimentation is a necessary element in understanding hypersonic flows, and must be engaged in more intensively in order to: (1) formulate models for inclusion in numerical design tools; (2) validate assembled CFD tools for accuracy; and (3) generate design data. It is presently noted that insufficient interaction exists between numerical and experimental methods at present, as illustrated by the literature's stress on numerics at the expense of critical experimentation for the validation of theoretical methods' capabilities. There is felt to be insufficient test hardware and instrumentation. O.C.

A89-33640#
COMPUTATIONAL METHODS FOR HYPERSONIC FLOWS - SPECIAL TECHNIQUES AND REAL GAS EFFECTS
H. HOLLANDERS, L. MARRAFFA, J. L. MONTAGNE, PH. MORICE, and H. VIVIAND University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 68 p. refs

Some aspects of computational methods for hypersonic flows are discussed. The general equations governing frozen or equilibrium gas flows are reviewed and examples of methods based on explicit and implicit schemes developed to solve the time-dependent Navier-Stokes equations for perfect gas are presented. Computational techniques for the treatment of stiff source terms are described. K.K.

A89-33641*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TURBULENCE MODELING FOR HYPERSONIC FLOWS
J. G. MARVIN and T. J. COAKLEY (NASA, Ames Research Center, Moffett Field, CA) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 48 p. refs

Turbulence modeling for high speed compressible flows is described and discussed. Starting with the compressible Navier-Stokes equations, methods of statistical averaging are described by means of which the Reynolds-averaged Navier-Stokes equations are developed. Unknown averages in these equations are approximated using various closure concepts. Zero-, one-, and two-equation eddy viscosity models, algebraic stress models and Reynolds stress transport models are discussed. Computations of supersonic and hypersonic flows obtained using several of the models are discussed and compared with experimental results. Specific examples include attached boundary layer flows, shock wave boundary layer interactions and compressible shear layers. From these examples, conclusions regarding the status of modeling and recommendations for future studies are discussed. Author

A89-33644#
NUMERICAL SIMULATION OF THREE-DIMENSIONAL HYPERSONIC VISCOUS FLOWS
W. KORDULLA, B. MUELLER, S. RIEDELBAUCH, W. WETZEL, and G. BRENNER (DFVLR, Goettingen, Federal Republic of Germany) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 49 p. refs
(Contract DFG-RU-334/1-6)

Numerical approaches to the simulation of viscous hypersonic flows in the continuum- as well as the gaskinetic-flow regimes are discussed with attention given to three-dimensional flows. The ideal-gas continuum flow is simulated using an explicit/implicit finite-difference method for the thin-layer approximation of the time-dependent Navier-Stokes equations. In the two dimensional case, real-gas effects are implemented using curve-fitting routines for the air properties in chemical equilibrium. K.K.

A89-33645#
LAMINAR-TURBULENT TRANSITION PROBLEMS AT HIGH SPEEDS
DANIEL ARNAL (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 39 p. refs

This paper is devoted to a description of some theoretical and experimental problems related with boundary layer transition at high speeds, in a two-dimensional mean flow. On the theoretical point of view, emphasis is given on linear stability theory, which describes the first stages of the transition process. In incompressible flow, it is often associated with the e(n) method for predicting transition onset. The extension of this method to compressible flows will be discussed. Another problem is to model the transition region, the extent of which becomes very large in hypersonic conditions,. This can be done by using an intermittency method. Some comparisons with experimental results are presented. In the last part of the paper, the problem of boundary layer tripping by isolated, three-dimensional roughness elements is discussed. Author

A89-33646#
HYPERSONIC BOUNDARY-LAYER TRANSITION
K. F. STETSON University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 100 p. refs

Hypersonic boundary-layer instability phenomena are described as well as parameteric trends. Attention is given to the effect of Mach number, nosetip bluntness, crossflow, unit Reynolds number, environment, wall temperature, surface roughness, mass transfer, and vibration. Prediction methods and prediction methodology are discussed as well. K.K.

A89-33735*# United Technologies Corp., Windsor Locks, CT.
NEAR WAKES OF ADVANCED TURBOPROPELLERS
D. B. HANSON (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) and W. P. PATRICK (United Technologies Research Center, East Hartford, CT) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 13 p. Research supported by United Technologies Corp. refs
(Contract NAS3-23720)
(AIAA PAPER 89-1095)

The flow in the wake of a model single rotation Prop-Fan rotor operating in a wind tunnel was traversed with a hot-wire anemometer system designed to determine the 3 periodic velocity components. Special data acquisition and data reduction methods were required to deal with the high data frequency, narrow wakes, and large fluctuating air angles in the tip vortex region. The model tip helical Mach number was 1.17, simulating the cruise condition. Although the flow field is complex, flow features such as viscous velocity defects, vortex sheets, tip vortices, and propagating acoustic pulses are clearly identified with the aid of a simple analytical wake theory. Author

A89-33758#
EXPERIMENTAL VALIDATION OF A LIFTING SURFACE MODEL FOR ROTOR WAKE-STATOR INTERACTION
J. B. H. M. SCHULTEN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 8 p. Research supported by the Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs
(AIAA PAPER 89-1125)

In most current turbofan engines, the interaction between fan wakes and the outlet guide vanes in the by-pass duct or the inlet guide vanes of the core engine, is the major noise-generating mechanism. A set of complet and clean experimental data on rotor/stator interaction has become available, which adds significanctly to the existing material. In the present paper these data are used for a detailed comparison with results of a lifting surface method. Despite an unsteady normal velocity up to 20 percent of the main velocity, a good agreement between measured and computed vane pressures is found. Author

A89-33783
NONLINEAR KINK MODES FOR SUPERSONIC VORTEX SHEETS
MIGUEL ARTOLA and ANDREW J. MAJDA (Princeton University, NJ) Physics of Fluids A (ISSN 0899-8213), vol. 1, March 1989, p. 583-596. refs
(Contract NSF DMS-87-02864; DAAL03-86-K-0003; N00014-85-K-0507; N00014-86-K-0759)

Both recent large-scale numerical simulations and time-dependent asymptotic nonlinear wave theories reveal the prominence of kink modes in the nonlinear instability of supersonic vortex sheets. These kink modes are nonlinear traveling waves that move along the vortex sheet at various speeds and have a wave structure consisting of a kink in the slip stream bracketed by shocks and rarefactions emanating from each side of the kink. Here an explicit construction is developed for calculating all the nonlinear kink modes that bifurcate from a given unperturbed contact discontinuity. This construction is applied at small amplitudes to provide a completely independent confirmation of the asymptotic nonlinear wave theories through a static bifurcation analysis. For the unperturbed vortex sheet, bifurcation diagrams at large amplitudes are also computed for several interesting density ratios and Mach numbers. These results are applied at large amplitude to explain some of the phenomena observed in numerical simulations. Author

A89-34114
VISCOSITY EFFECTS IN THE GENERATION OF THE LIFTING FORCE OF AERODYNAMIC WING PROFILES [VIAZKOSTNYE EFFEKTY PRI FORMIROVANII POD'EMNOI SILY AERODINAMICHESKIKH PROFILEI KRYL'EV]
L. F. KOZLOV and V. A. KOCHIN (AN USSR, Institut Gidromekhaniki, Kiev, Ukrainian SSR) Bionika (ISSN 0374-6569), no. 22, 1988, p. 1-12. In Russian. refs

A generalized Zhukovski-Chaplygin postulate is formulated which corresponds in particular cases to the Taylor-Howarth and other criteria. It is shown that the classical Zhukovski-Chaplygin postulate, based on qualitative results of flow visualization, approximately reflects the actual situation in the case of stationary flow past wing profiles with a sharp trailing edge. For profiles with a rounded trailing edge and nonstationary flow past aerodynamic profiles, the generalized Zhukovski-Chaplygin postulate should be used which allows for viscosity effects in the generation of the lifting force of aerodynamic wing profiles. V.L.

A89-34149
NUMERICAL MODELING OF TRANSONIC FLOW OF A VISCOUS GAS IN A PLANE CHANNEL WITH A SUDDEN EXPANSION [CHISLENNOE MODELIROVANIE TRANSZVUKOVOGO TECHENIIA VIAZKOGO GAZA V PLOSKOM KANALE PRI VNEZAPNOM RASSHIRENII]
V. K. BULGAKOV, A. M. LIPANOV, A. M. ROSLOV, and O. A. TIMOFEEV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 89-91. In Russian. refs

Flow of a viscous gas in a suddenly expanding channel is investigated in the transonic velocity region using a system of full Navier-Stokes equations. The system of equations with the corresponding boundary conditions is solved numerically using an implicit splitting scheme. The results obtain indicate that the Reynolds number affects the length of the separation zone but has practically no effect on the base pressure beyond the step. The analytical results are found to generally agree with experimental data to within 10-15 percent. V.L.

A89-34151
ANALYSIS OF SEPARATED FLOW PAST A THIN PROFILE IN THE CASE OF TRANSLATIONAL OSCILLATIONS [RASCHET OTRYVNOGO OBTEKANIIA TONKOGO PROFILIA PRI POSTUPATEL'NYKH KOLEBANIIAKH]
O. IU. KOROTKOV and G. M. SHUMSKII Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 92-94. In Russian. refs

The paper is concerned with the translational oscillations of a thin rectilinear profile (a plate) in the path of separated flow of an ideal incompressible fluid. In particular, the effect of the amplitude and frequency of the forced oscillations of the profile on its aerodynamic characteristics is investigated by means of a numerical experiment. Vortex formation processes typical of such flows are examined. V.L.

A89-34152
OPTIMAL PROFILE SELECTION IN THE DESIGN OF A SUBSONIC TURBINE CASCADE [K VYBORU OPTIMAL'NOGO PROFILIA V PROEKTIRUEMOI DOZVUKOVOI RESHETKE TURBINY]
B. I. MAMAEV and T. I. SHUVEROVA Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 94-96. In Russian.

An analytical/experimental study has been conducted to investigate the possibility of optimizing the performance characteristics of subsonic turbine cascades by varying their geometry. In particular, pressure distributions over cascade profiles are determined for different geometric parameters of the profiles. The pressure distribution characteristics are explained in terms of curvature distribution over the profile. V.L.

A89-34427*# Sterling Software, Palo Alto, CA.
ADVANCES IN THE COMPUTATION OF TRANSONIC SEPARATED FLOWS OVER FINITE WINGS
UNVER KAYNAK (Sterling Software, Inc., Palo Alto, CA) and JOLEN FLORES (NASA, Ames Research Center, Moffett Field, CA) Computers and Fluids (ISSN 0045-7930), vol. 17, no. 2, 1989, p. 313-332. refs
(Contract NCA2-OR-745-309; NAS2-11555)

Problems encountered in numerical simulations of transonic wind-tunnel experiments with low-aspect-ratio wings are surveyed and illustrated. The focus is on the zonal Euler/Navier-Stokes program developed by Holst et al. (1985) and its application to shock-induced separation. The physical basis and numerical implementation of the method are reviewed, and results are presented from studies of the effects of artificial dissipation, boundary conditions, grid refinement, the turbulence model, and geometry representation on the simulation accuracy. Extensive graphs and diagrams and typical flow visualizations are provided. T.K.

A89-34461
LARGE-EDDY SIMULATIONS OF EXCITATION EFFECTS ON A VTOL UPWASH FOUNTAIN
MAGDI H. RIZK and SURESH MENON (Flow Research Co., Kent, WA) Physics of Fluids A (ISSN 0899-8213), vol. 1, April 1989, p. 732-740. refs
(Contract F49620-85-C-0084)

In the present investigation of a VTOL aircraftlike propulsion system upwash fountain's response to various azimuthal and axisymmetric excitations, kinematic considerations are used to ascertain the interactions of large-scale structures in the fountain, as well as the effects of these interactions on fountain characteristics. The flow is assumed to be governed by the time-dependent, incompressible Navier-Stokes equations. Distinct fountain characteristics are found to be shared among the cases in which azimuthal perturbations are applied at both jet exits. A strong resemblance also exists for the cases of azimuthal and axisymmetric forcings in opposite directions at the two jet exits. O.C.

A89-34621
A NEW LOOK AT THEODORSEN'S METHOD IN AEROFOIL THEORY
RAJENDRA K. BERA (National Aeronautical Laboratory, Bangalore, India) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 9, March 1989, p. 251-262. refs

Theodorsen's (1931) method for calculating the incompressible potential flow past an aerofoil is reviewed. It is found that some simple modifications to the computational process make the computations relatively faster, easier, and more accurate. The new modifications are applicable to the analysis of conventional airfoils with up to moderate thickness and camber ratio. Several examples are presented to show the effectiveness of the modifications. Author

A89-34627
VISCOUS-INVISCID INTERACTION AND COMPUTATION IN AERODYNAMICS
J. C. LE BALLEUR (ONERA, Chatillon-sous-Bagneux, France) IN: BAIL V; Proceedings of the Fifth International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods, Shanghai, People's Republic of China, June 20-24, 1988. Dublin, Ireland, Boole Press, Ltd., 1988, p. 30-41. refs
(ONERA, TP NO. 1988-116)

A short survey of progress in viscous-inviscid formulation and numerical coupling algorithms is given, for computation in high Reynolds number aerodynamics. The 'defect formulation' is shown to provide a unified development, both for boundary-layerlike and Navier-Stokes solvers. Thin-layer solvers are efficiently developed with interacted integral equations, closed with a velocity profile modeling and a two-half-equation turbulence model. The original semiinverse coupling method is suggested in steady flows, and a time-consistent semiimplicit method in unsteady flows. With these, the viscous-inviscid numerical technique is now capable to compute without limitations the complex separation processes. Results are shown for computation of massive separation and stall, of shock-boundary layer interactions, and of unsteady separation with transonic buffet. Author

A89-34646* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
HIGH-RESOLUTION SHOCK-CAPTURING SCHEMES FOR INVISCID AND VISCOUS HYPERSONIC FLOWS
H. C. YEE (NASA, Ames Research Center, Moffett Field, CA), G. H. KLOPFER (Nielsen Engineering and Research, Inc., Mountain View, CA), and J.-L. MONTAGNE (NASA, Ames Research Center, Moffett Field, CA; ONERA, Chatillon-sous-Bagneux, France) IN: BAIL V; Proceedings of the Fifth International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods, Shanghai, People's Republic of China, June 20-24, 1988. Dublin, Ireland, Boole Press, Ltd., 1988, p. 417-423. refs

The development of robust, accurate, and efficient implicit shock-capturing schemes for multidimensional compressible Navier-Stokes equations in the hypersonic and real gas flow regimes is presently undertaken by extending a class of implicit total variation-diminishing (TVD) schemes suitable for transonic and supersonic, multidimensional Euler and Navier-Stokes equations to hypersonic computations. Numerical aspects of TVD schemes are identified which affect the convergence rate for hypersonic Mach numbers and real gas flows, but which have a negligible effect on low Mach number or perfect gas flows. O.C.

A89-34726
ADVANCES AND APPLICATIONS IN COMPUTATIONAL FLUID DYNAMICS; PROCEEDINGS OF THE SYMPOSIUM, ASME WINTER ANNUAL MEETING, CHICAGO, IL, NOV. 27-DEC. 2, 1988
OKTAY BAYSAL, ED. (Old Dominion University, Norfolk, VA) Symposium sponsored by ASME, Fluid Engineering Division. New York, American Society of Mechanical Engineers, 1988, 217 p. For individual items see A89-34727 to A89-34747.

Various papers on advances and applications in computational fluid dynamics are presented. Individual topics considered include: applications or domain decomposition methods to turbomachinery forces, patched-grid computations of high-speed inlet flows, turbulent flow computations in an angled duct with a step, Navier-Stokes calculations of scramjet-afterbody flowfields, incompressible cascade calculations using an upwind differenced TVD scheme, Euler solver for 3D inverse problems, iterative acceleration and physically based dissipation for Euler equations of gasdynamics, and noniterative solution for pressure in parabolic flows. Also addressed are: higher order scheme for convective flows, use of modified finite element method for CFD applications, Navier-Stokes calculations of transonic flows past open and transitional cavities, Navier-Stokes simulation of unsteady three-dimensional blade-vortex interactions, and stream function formulation for natural convection in a multiply connected enclosure. C.D.

A89-34728* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PATCHED-GRID COMPUTATIONS OF HIGH-SPEED INLET FLOWS
J. L. THOMAS, D. H. RUDY (NASA, Langley Research Center, Hampton, VA), S. R. CHAKRAVARTHY (Rockwell International Science Center, Thousand Oaks, CA), and R. W. WALTERS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 11-22. refs

Two implicit algorithms for the compressible Navier-Stokes equations are applied to the computation of high-speed inlet flows typical of those which are encountered on propulsion systems of advanced hypersonic vehicles. A patched grid formulation is used to treat accurately the blunt cowl interaction with the forebody compression field and efficiently treat variations in inlet geometry downstream of the inlet entrance. Results from the two algorithms, each based on an upwind-biased spatial differencing approach for the convective and pressure terms within a flux-difference-splitting framework, are compared with experimental results for both inlets, and reasonable agreement is found. C.D.

A89-34730* Florida Univ., Gainesville.
A SELF-ADAPTIVE COMPUTATIONAL METHOD FOR TRANSONIC TURBULENT FLOW PAST A REAL PROJECTILE
C.-C. HSU, N.-H. SHIAU (Florida, University, Gainesville), and W.-J. CHYU (NASA, Ames Research Center, Moffett Field, CA) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 33-41. refs
(Contract NAG2-2473)

An attempt to develop an effective solution-adaptive computational method for complex unsteady flow problems is reported. The adaptive grid generation technique is critically examined to understand its application to self-adaptive computational procedures. A complex flow problem involving an impulsive Mach 0.96 transonic turbulent flow past a real secant-ogive-cylinder-boattail projectile, including the base flow region at zero angle of attack, is considered. The coupling of the grid generation code to the unsteady Navier-Stokes code makes it possible to generate a new grid network adaptive to the computed solution at every time step. C.D.

A89-34732* Old Dominion Univ., Norfolk, VA.
NAVIER-STOKES CALCULATIONS OF SCRAMJET-AFTERBODY FLOWFIELDS
O. BAYSAL, W. C. ENGELUND (Old Dominion University, Norfolk, VA), and K. E. TATUM (NASA, Langley Research Center, Hampton, VA) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 49-59. refs
(Contract NAG1-811)

Scramjet simulant-gas exhaust flows are computed using

two-dimensional Navier-Stokes (NS) equations. The NS equations are solved using an implicit, upwind, finite-volume scheme, and the Reynolds stresses are modeled algebraically. The solutions are compared with experimental data where the freestream and the nozzle exhaust fluids are air. The NS equations for the flow, where the scramjet exhaust simulant gas is a mixture of Freon-12 and argon, are solved by an explicit, finite difference scheme. The results are compared with experimental data, and certain discrepancies are explained. C.D.

A89-34733
INCOMPRESSIBLE CASCADE CALCULATION USING AN UPWIND DIFFERENCED TVD SCHEME
J. J. GORSKI (U.S. Navy, David W. Taylor Naval Ship Research and Development Center, Bethesda, MD) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 61-69. refs
(Contract N00024-86-WR-10432)

A reliable and robust method has been developed for solving the incompressible flow Navier-Stokes equations in two dimensions. The method is based on an upwind differenced TVD scheme which requires no numerical parameters to be changed for the different calculations. Comparisons with data for three different cascades demonstrate the accuracy of the method for ideal and flat plate cascades. C.D.

A89-34736
INVISCID PREDICTION OF TRANSONIC FLOWS IN TURBOMACHINES USING A RUNGE-KUTTA INTEGRATION SCHEME
A. ARNONE and S. S. STECCO (Firenze, Universita, Florence, Italy) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 93-100. refs

A computer code for solving the Euler equations has been developed and applied on H-grids for turbomachinery flowfield prediction. The integration in time is based on an explicit four-stage Runge-Kutta scheme. Linear interpolations are used for spatial discretization and care was taken in maintaining global conservation and the smoothing character of the dissipative terms. Comparison with inviscid theoretical solutions and with experimental data shows that the method is an accurate inviscid solver and can be applied to turbomachinery to yield a good blade-to-blade prediction. Author

A89-34737
COMPUTATIONAL STUDY OF THE EFFECT OF CASCADE PARAMETERS ON STALL PROPAGATION IN AXIAL COMPRESSORS
F. SISTO, S. JONNAVITHULA, and S. THANGAM (Stevens Institute of Technology, Hoboken, NJ) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 101-107. refs
(Contract N00014-86-K-0315; N62271-87-M-0204)

Propagating stall in a linear cascade of airfoils is simulated using a vortex tracking method. The imposed periodicity of the vortex arrays is shown to constrain the occurrence of stable propagating stall to a limited range of flow and geometric parameters. Within this stable range, the method is insensitive to the nonphysical parameters, and hence is quite robust. The role of a vortex merging algorithm in the method is examined in detail, and recent improvements are discussed. A systematic parametric study is conducted within the stable ranges to extend the available results, and conclusions are drawn concerning the key parameter of interblade phase angle or its surrogate the stall patch wavelength at a specified frequency. C.D.

A89-34740*
SECOND ORDER ACCURATE FINITE DIFFERENCE APPROXIMATIONS FOR THE TRANSONIC SMALL DISTURBANCE EQUATION AND THE FULL POTENTIAL EQUATION
M. M. MOSTREL (Bell Communications Research, Inc., Piscataway, NJ) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 129-143. refs
(Contract N00014-86-K-0691; NAG2-70)

New shock-capturing finite difference approximations for solving two scalar conservation law nonlinear partial differential equations describing inviscid, isentropic, compressible flows of aerodynamics at transonic speeds are presented. A global linear stability theorem is applied to these schemes in order to derive a necessary and sufficient condition for the finite element method. A technique is proposed to render the described approximations total variation-stable by applying the flux limiters to the nonlinear terms of the difference equation dimension by dimension. An entropy theorem applying to the approximations is proved, and an implicit, forward Euler-type time discretization of the approximation is presented. Results of some numerical experiments using the approximations are reported. C.D.

A89-34744* Old Dominion Univ., Norfolk, VA.
NAVIER-STOKES CALCULATIONS OF TRANSONIC FLOWS PAST OPEN AND TRANSITIONAL CAVITIES
S. SRINIVASAN, O. BAYSAL (Old Dominion University, Norfolk, VA), and E. B. PLENTOVICH (NASA, Langley Research Center, Hampton, VA) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 169-179. refs
(Contract NCC1-121)

Computational simulations of deep and transitional cavities at transonic regimes were performed. The three-dimensional unsteady separation on the cavity floor was analyzed, and computational flow visualization inside the cavity was done. A parametric study was performed to investigate the effects of varying Mach number and the ratio delta/D, where delta is the instantaneous boundary layer thickness at the upstream lip and D is the depth. Both time-averaged and instantaneous solutions were obtained. Comparison of the solutions with experimental data were generally favorable; some discrepancies are explained. C.D.

A89-34745* JAI Associates, Mountain View, CA.
NAVIER-STOKES SIMULATION OF UNSTEADY THREE-DIMENSIONAL BLADE-VORTEX INTERACTIONS
G. R. SRINIVASAN (JAI Associates, Inc., Mountain View, CA) and W. J. MCCROSKEY (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 181-186. refs
(Contract DAAL03-88-C-0006)

The unsteady, viscous, three-dimensional flow field of a helicopter rotor blade encountering a passing vortex is calculated by solving the thin layer Navier-Stokes equations by a finite-difference numerical procedure. A prescribed vortex method is adopted to preserve the structure of the interacting concentrated vortex. The test cases considered correspond to the experimental model rotor test conditions of Caradonna et al. Author

A89-34746
A LINEAR COMPUTER CODE TO DETERMINE AEROELASTIC STABILITY IN AIRFOIL CASCADES AT UNSTEADY FLOW CONDITIONS
S. S. STECCO and L. MARCHI (Firenze, Universita, Florence, Italy) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual

Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 187-193. Research supported by the Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative and CNR. refs

The aerodynamic behavior of an oscillating elastic cascade in nonuniform subsonic flow is investigated analytically, applying the potential solution obtained by Marchi (1987) to define the blade pressure distributions which bound the overall linearized problem. The derivation of the model equations is outlined; the solution procedure is explained; and numerical results from simulations of torsional vibrations and gusts in different flat-plate and curved-plate configurations are presented in extensive graphs and characterized in detail, including the effects of interblade vibrational phase angle, stagger angle, pitch/cord ratio, reduced vibration frequency, and flow Mach number. The behavior of flat- and curved-plate cascades is found to be identical, suggesting the use of flat-plate cascades as a reference in unsteady design analyses. T.K.

A89-34749
THIN AEROFOILS WITH HIGH-INCIDENCE FLAPS OR BLUNT TRAILING EDGES
J. A. MORIARTY and E. O. TUCK (Adelaide, University, Australia) Aeronautical Journal (ISSN 0001-9240), vol. 93, March 1989, p. 93-99. refs

The method of matched asymptotic expansions is used to calculate the lift for a class of thin aerofoils with high-incidence flaps or blunt trailing edges. The analysis is based on smallness of the ratio between the flap length (or trailing-edge thickness) and the chord of the main foil. Results are compared with exact solutions for bent plates and for triangular and quadrilateral bodies. A procedure for extension to general trailing-edge configurations, including detached flaps, is outlined. Author

A89-34807#
EVALUATION OF ALGEBRAIC TURBULENCE MODELS FOR PNS PREDICTIONS OF SUPERSONIC FLOW PAST A SPHERE-CONE
SIAMACK A. SHIRAZI and C. RANDALL TRUMAN (New Mexico, University, Albuquerque) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 560-568. Research supported by Sandia National Laboratories. Previously cited in issue 08, p. 1043, Accession no. A87-22696. refs

A89-34809*# Virginia Univ., Charlottesville.
LASER-INDUCED IODINE FLUORESCENCE TECHNIQUE FOR QUANTITATIVE MEASUREMENT IN A NONREACTING SUPERSONIC COMBUSTOR
D. G. FLETCHER and J. C. MCDANIEL (Virginia, University, Charlottesville) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 575-580. Previously cited in issue 09, p. 1191, Accession no. A87-24916. refs
(Contract NAG1-373)

A89-34811#
TRANSITIONAL FLOW ON AXIAL TURBOMACHINE BLADING
G. J. WALKER (U.S. Naval Postgraduate School, Monterey, CA) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 595-602. Previously cited in issue 08, p. 1032, Accession no. A87-22356. refs

A89-34819#
NUMERICAL INSTABILITIES IN THE CALCULATION OF LAMINAR SEPARATION BUBBLES AND THEIR IMPLICATIONS
TUNCER CEBECI (Douglas Aircraft Co., Long Beach, CA) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 656-658. refs
(Contract F49620-84-C-0007)

The prediction of separation bubbles on airfoils is presently undertaken by using both linear stability theory and the e exp n method to ascertain transitions based on calculated velocity profiles. An examination is then conducted of the leading-edge separation bubble on a thin airfoil as a function of angle-of-attack and for Reynolds numbers of up to 100,000. This systematic study has been so structured as to allow especially careful examination of the relationship between the growth of the separated region and transition. O.C.

A89-34883#
MODEL FOR INVESTIGATION OF HELICOPTER FUSELAGE INFLUENCE ON ROTOR FLOWFIELDS
OMRI RAND and ALFRED GESSOW (Maryland, University, College Park) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 401, 402. Research supported by the U.S. Army. refs

The paper presents an efficient analytical model for analyzing helicopter fuselage effects on main rotor flowfields in various flight conditions. The fuselage shapes are obtained by a discrete distribution of point and line sources/sinks along their axes which, together with the freestream velocity, create bodies with two planes of symmetry. It is shown that the method enables the description of a large family of helicopter-like shapes with very few sources. Small fuselage yaw angles are introduced by slender body theory. The paper also includes an explicit slender-body approximation for taking into account an arbitrary distribution of main rotor downwash over the fuselage surface. The model is used for parametric investigation of the fuselage influence for a variety of shapes, flight conditions, and rotor/fuselage relative positions. Author

A89-34884*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WIND-TUNNEL WALL EFFECTS ON DELTA WINGS
NEAL T. FRINK (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 403, 404. Abridged. Previously cited in issue 21, p. 3338, Accession no. A87-49089.

A89-34886#
EFFECT OF WING TIP STRAKES ON WING LIFT-DRAG RATIO
EN-CHUN MA (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 410-416.

The objective is to increase the wing lift-drag ratio by vortex induction method generated with wing tip strakes. Experimental results for a rectangular wing of aspect ratio 5 equipped with wing tip strakes indicated that the flat-plate strake was worse than a strake with dihedral angle and thickness for increasing the wing lift-drag ratio. Strakes cut off at 45 deg were the best at increasing the wing lift-drag ratio, while strakes with delta = 0 deg were the best at improving the ratio. Author

A89-34887#
NUMERICAL SOLUTIONS FOR THE FLOWFIELD AROUND A COUNTER-ROTATING PROPELLER
MAKOTO KOBAYAKAWA (Kyoto University, Japan) and MASAHIRO NAKAO (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 417-422. refs

Three-dimensional Euler equations are used to investigate the flowfield around a counter-rotating propeller in flight at a Mach 0.8. Two volumes including front and rear blades are solved separately. The interaction between both blades is included in the calculation by the connecting surfaces. The non-iterative implicit ADI (alternating direction implicit) scheme is used in order to solve the Euler equations. The periodic steady solution is obtained. This simulates the relative motion of the blades exactly. Numerical calculations are performed for a counter-rotating propfan with SR-3 blade configurations. The results show that the propeller efficiency is superior to that of a single-rotating propfan with the same number of blades. Author

A89-34892*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EULER AND NAVIER-STOKES LEESIDE FLOWS OVER SUPERSONIC DELTA WINGS
S. N. MCMILLIN, J. L. THOMAS (NASA, Langley Research Center, Hampton, VA), and E. M. MURMAN (MIT, Cambridge, MA) Journal

of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 452-458. Previously cited in issue 21, p. 3335, Accession no. A87-49053. refs
(Contract N00014-86-K-0288)

A89-34893#
TRANSONIC BUFFET OF A SUPERCRITICAL AIRFOIL WITH TRAILING-EDGE FLAP
B. H. K. LEE and F. C. TANG (National Research Council of Canada, High Speed Aerodynamics Laboratory, Ottawa) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 459-464. refs

A supercritical airfoil with a trailing-edge flap was tested at the High Reynolds Number Two-Dimensional Test Facility of the National Aeronautical Establishment. Buffet boundaries at various flap angles were determined from the divergence of the indicated normal-force fluctuations. The test was performed quite deep into the buffet regime of the airfoil, and spectral analyses of the unsteady normal force showed shock-wave oscillations of approximately 50-80 Hz for Mach numbers between 0.612 and 0.792. The drag of the airfoil was measured from wake probes, and the drag penalties for the large flap angles were quite significant. This study illustrates the use of trailing-edge flaps for buffet alleviation at transonic conditions. Author

A89-34895*# Johnson Aeronautics, Palo Alto, CA.
CALCULATION OF BLADE-VORTEX INTERACTION AIRLOADS ON HELICOPTER ROTORS
WAYNE JOHNSON (Johnson Aeronautics, Palo Alto, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 470-475. Research sponsored by the U.S. Army. refs
(Contract NAS2-12767)

Two alternative approaches area developed to calculate blade-vortex interaction airloads on helicopter rotors, second-order lifting-line theory and a lifting-surface theory correction. The common approach of using a larger vortex core radius to account for lifting-surface effects is quantified. The second-order lifting-line theory also improves the modeling of low aspect-ratio blades yawed flow, and swept tips. Calculated results are compared with wind-tunnel measurements of lateral flapping, and with flight test measurements of blade section lift on SA349/2 and H-34 helicopter rotors. The tip vortex core radius required for good correlation with the flight test data is about a 20-percent chord, which is within the range of measured viscous core sizes for helicopter rotors. Author

A89-34898#
INDUCED DRAG AND THE IDEAL WAKE OF A LIFTING WING
C. W. MCCUTCHEN (NIH, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 489-493. refs

The wake of a lifting wing in inviscid flow is a pair of downward-sloping vortices with distributed vorticity in which the vortex lines are approximately helical. Suction in the vortex cores counterbalances the negative momentum drag, and the difference between the two is the induced drag, which is presently characterized as the integral over any transverse plane behind the wing of the difference between the energies of lateral and longitudinal motion per unit length. The drag contribution of the portion of the wing lying between any two transverse planes is equal to the growth of this integral between the forward and the rear planes. O.C.

A89-34934
A COMPARISON OF SECONDARY FLOW IN A VANE CASCADE AND A CURVED DUCT
M. T. BOYLE, M. SIMONDS (Maine, University, Orono), and K. POON (Textron Lycoming, Stratford, CT) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 85-93. Research supported by Textron Lycoming. refs

An experimental study has been conducted to ascertain the aerodynamic characteristics of three-dimensional flow through a linear cascade of turbine vanes; the results obtained are compared with those for a duct whose shape is similar to that of the cascade passage. While the qualities of these two viscous flows are very similar (except in the leading-edge region), the secondary flow is stronger in the duct passage than in the vane cascade passage. The effect on cascade passage flow of a horseshoe vortex generated around the leading edge of each vane is noted to be limited to the leading edge/endwall-junction region. O.C.

A89-35053*# San Diego State Univ., CA.
EFFECT OF 90 DEGREE FLAP ON THE AERODYNAMICS OF A TWO-ELEMENT AIRFOIL
J. KATZ (San Diego State University, CA) and R. LARGMAN ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202), vol. 111, March 1989, p. 93, 94. refs
(Contract NCC2-458)

The aerodynamic performance of a two-element airfoil with a 90-deg trailing edge flap was experimentally investigated. The 5 percent-chord long flap, significantly increased the lift of the baseline airfoil, throughout a wide range of angles of attack. The maximum lift coefficient of the flapped wing increased too, whereas the lift/drag ratio decreased. Author

A89-35168
CALCULATION OF COMPRESSION SHOCK SURFACES IN THREE-DIMENSIONAL, STEADY SUPERSONIC FLOWS USING A BICHARACTERISTIC METHOD [BERECHNUNG VON VERDICHTUNGSSTOSSFLAECHEN IN RAEUMLICHEN, STATIONAEREN UEBERSCHALLSTROEMUNGEN MIT EINEM BICHARAKTERISTIKENVERFAHREN]
W. JULING and J. BALLMMANN (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 12, Sept.-Dec. 1988, p. 313-322. In German. refs

This paper presents a numerical algorithm of second-order accuracy for use on shock surfaces in three-dimensional supersonic flowfields. The algorithm is based on the steady-state three-dimensional method of characteristics. The method used for the shock uses a local grid made up of four bicharacteristics on the streamline before the shock, five bicharacteristics behind the shock, and one shock surface-generating line. The scheme is an iterative predictor-corrector algorithm where two of the unknown flow variables behind the shock are used as control variables. It is shown that pressure is unsuitable for this purpose. Computed solutions in which a shock surface present in the three-dimensional flowfields is either included or ignored illustrate the capabilities of the method. C.D.

A89-35172
INVESTIGATION OF FLOW SEPARATION IN A THREE-DIMENSIONAL DIFFUSER USING A COUPLED EULER AND BOUNDARY-LAYER METHOD
H. W. STOCK, S. LEICHER, and W. SEIBERT (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 12, Sept.-Dec. 1988, p. 347-357. Research supported by BMFT. refs

The causes of flow separation in an empty, small-scale model of the European Transonic Wind Tunnel (ETWT) diffuser are numerically investigated. The three-dimensional nature of the flow, its generation mechanism, and is influence on flow separation are studied. The inviscid flow is calculated by a three-dimensional finite volume method for the solution of the Euler equations, and the viscous flow on the diffuser wall is evaluated by a boundary-layer method for three-dimensional, compressible turbulent flow. The boundary-layer information is transferred as a boundary condition to the inviscid method via the outflow concept. It is shown that the diffuser geometry is responsible for the flow separation. Agreement is found between experimental results

obtained in a small-scale ETWT test rig diffuser and the numerical ones. C.D.

A89-35195#
THREE-DIMENSIONAL BOUNDARY-LAYER TRANSITION STUDY
Y. KOHAMA (Tohoku University, Sendai, Japan) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 145-157. refs

This paper deals with brief survey of three-dimensional (3-D) boundary-layer transition in axisymmetric spinning bodies, curved walls (concave, convex walls, swept bodies) and flat plate with pressure gradient which being the fundamental study for LFC wing. Particular attention is made to clarify the transition process and coherent structure in 3-D boundary-layer transition is suggested. Author

A89-35214#
A PRELIMINARY CHARACTERIZATION OF PARACHUTE WAKE RECONTACT
JAMES H. STRICKLAND and J. MICHAEL MACHA (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 78-85. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0897)

A series of tests was conducted on a 10-ft-diameter ringslot parachute with a geometric porosity of 20 percent to establish the conditions under which wake recontact occurs. The vertical helicopter drop tests covered a range of mass ratios from 0.5 to 3.0 and a range of Froude numbers from 70 to 400. Data consisted of velocity time histories obtained using a laser tracker and diameter time histories obtained from photometric data. A collapse parameter based on the ratio of the maximum parachute diameter to the subsequent minimum diameter was correlated with the mass ratio and the Froude number or equivalently with the initial to final velocity ratio. Author

A89-35215#
FLOW VISUALIZATION STUDIES OF WAKE BEHIND AXISYMMETRIC BLUFF BODIES INCLUDING PARACHUTE CANOPY MODELS
HIROSHI HIGUCHI (Minnesota, University, Minneapolis) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 86-90. refs
(AIAA PAPER 89-0898)

Flow visualization study was conducted for various configurations of axisymmetric bluff body geometries including those of solid and ribbon parachute canopy models. The structures of the unsteady wake patterns were documented and analyzed. In addition, the effect of rapid model acceleration and deceleration on the wake was visualized. The results from photos and video are discussed. Author

A89-35216#
AN APPROXIMATE METHOD FOR CALCULATING AIRCRAFT DOWNWASH ON PARACHUTE TRAJECTORIES
JAMES H. STRICKLAND (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 91-96. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0899)

An approximate method for calculating velocities induced by aircraft on parachute trajectories is presented herein. A simple system of quadrilateral vortex panels is used to model the aircraft wing and its wake. The purpose of this work is to provide a simple analytical tool which can be used to approximate the effect of aircraft-induced velocities on parachute performance. Performance issues such as turnover and wake recontact may be strongly influenced by velocities induced by the wake of the delivering aircraft, especially if the aircraft is maneuvering at the time of parachute deployment. Author

A89-35218#
PREDICTION OF PARACHUTE COLLAPSE DUE TO WAKE RECONTACT
J. W. OLER (Texas Tech University, Lubbock) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 104-109.
(AIAA PAPER 89-0901)

The wake behind a decelerating parachute and payload may, in some instances, overtake and collapse the parachute. This paper presents an analytical model of the parachute and payload deceleration process including the wake development. Calculation results include the deceleration history, wake velocity distribution, and an indication of the occurrence of wake recontact. Author

A89-35241#
ANALYSIS OF DECELERATORS IN MOTION USING COMPUTATIONAL FLUID DYNAMICS
EARL C. STEEVES (U.S. Army, Research, Development and Engineering Center, Natick, MA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 269-278. refs
(AIAA PAPER 89-0931)

This paper presents results of work on the use of computational fluid dynamics to predict the behavior of aerodynamic decelerators. This investigation includes flow about stationary decelerators and a procedure to treat problems involving coupling between the decelerator motion and fluid motion, such as the terminal velocity problem. Computational results are presented for a flat, circular disk and include normal flow about a stationary disk, terminal velocity of a free-falling disk, a disk moving through a fluid with uniform acceleration and uniform velocity. These results show the numerical techniques to be reasonably successful in predicting the drag performance and terminal velocity. Author

A89-35243#
A COUPLING APPARENT MASS FOR PARACHUTE INFLATION EQUATIONS
D. F. WOLF (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 286-292. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0933)

A parachute inflation model based on a conservation of momentum equation was originally proposed to provide a predictive capability for new parachute designs. The original model predicted faster inflations and larger loads than those observed in test data. The differences were most significant for parachute systems which experienced large decelerations during the inflation process. A coupling apparent mass effect was proposed which reduces the inflation rates and loads. The effect is similar in form to the classical hydrodynamics description of coupling between degrees of freedom for an asymmetric body. An approximate value of 1 to 1.3 for the coupling apparent mass coefficient is estimated based on comparison with flight data for ribbon parachutes. Author

A89-35244#
AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC LOADS ON CAMBERED PLATES
J. H. LAWRENCE, J. W. OLER, and D. T. ADAMSON (Texas Tech University, Lubbock) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute

of Aeronautics and Astronautics, 1989, p. 293-296. refs
(AIAA PAPER 89-0935)

If the parachute deceleration of a payload results in a large momentum transfer to the surrounding fluid over a relatively short distance, the resulting wake velocities may be large enough for the wake to overtake and collapse the parachute. This paper describes an experimental test program aimed at investigating the aerodynamic interaction between the parachute and fluid during a wake recontact process. Author

A89-35250#
THE EFFECTS OF UNSTEADY AERODYNAMICS ON SINGLE AND CLUSTERED PARACHUTE SYSTEM
DONALD E. WAYE and DONALD W. JOHNSON (Sandia National Laboratories, Albuquerque, NM) AIAA, Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989. 8 p.
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0934)

A study was performed to evaluate the performance of equivalent drag area single parachute systems and cluster parachute systems during the early inflation and initial deceleration phase. Analytical work showed that the cluster system could exhibit better performance during this unsteady aerodynamic phase, due to a significant decrease in the apparent mass of air influenced by the parachutes. Two test programs have been performed in support of these assumptions. Author

A89-35381
EXPERIMENTAL WIND TUNNEL STUDY OF A MILITARY-AIRCRAFT AIR INTAKE - COMPARISON WITH FLIGHT [ETUDE EXPERIMENTALE D'UNE ENTREE D'AIR D'AVION MILITAIRE EN SOUFFLERIE - COMPARAISON AVEC LE VOL]
M. BOURASSEAU and M. RAPUC (Avions Marcel Dassault Breguet Aviation, Saint Cloud, France) (Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 134, 1989, p. 46-53. In French.

Wind tunnel techniques for evaluating the performance of military-aircraft air intakes in the subsonic and supersonic regimes are discussed. Wind-tunnel measurements for steady and unsteady flows are obtained and are numerically analyzed in real time. Spatial and temporal distortion of the internal flow is shown to result in a degradation of compressor performance. Wind-tunnel results for various Mach numbers, angles of incidence, and sideslip angles agree well with flight test data. R.R.

A89-35393#
THE CORRELATION BETWEEN REYNOLDS STRESS AND TURBULENT KINETIC ENERGY IN THE NEAR WAKE OF A SYMMETRIC AIRFOIL
KEMIN HE and XING TU (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, April 1989, p. 138-146. In Chinese, with abstract in English. refs

This paper describes the turbulent flow field in the trailing edge boundary layer and near wake of a NASA 63-012 symmetric airfoil in a low-speed wind tunnel and investigates the correlation between Reynolds stress and turbulent kinetic energy in near wake of the airfoil. It is shown that the distributions of the Reynolds stress and turbulent kinetic energy were similar for about 80 percent of the wake width, except for the region near the center line. Equations relating the Reynold stress and turbulent kinetic energy for the outer region of the wake and for the center region of the near wake are given. I.S.

A89-35417#
A NUMERICAL INVESTIGATION OF STEADY TRANSONIC CASCADE FLOW IN TURBOMACHINERY
KUEN-CHUAN WU and PONG-JEU LU (National Cheng Kung University, Tainan, Republic of China) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731), vol. 9, Aug. 1988, p. 229-240. refs

A finite difference method is presented which solves numerically the flow field about a cascade of two-dimensional airfoils. The method is a strongly conservative discretization of the full potential equation, with an artificial viscosity added in supersonic regions to ensure the stability and the capture of shock waves. All computations are performed on a C-type, body-fitted grid which is generated by a sequence of conformal and shear transformations. The concept of artificial time is applied for the development of a convergent successive line over-relaxation (SLOR) scheme. Results of using NACA0012 airfoils as cascade blades are illustrated and compared with data from other sources. The agreement is in general quite satisfactory. Author

A89-35430
A COMBINED METHOD FOR CALCULATING SUPERSONIC FLOW OF AN IDEAL GAS PAST A WING WITH A SUPERSONIC BLUNT LEADING EDGE [KOMBINIROVANNYI METOD RASCHETA SVERKHZVUKOVOGO OBTEKANIIA KRYLA SO SVERKHZVUKOVOI ZATUPLENNOI PEREDNEI KROMKOI IDEAL'NYM GAZOM]
N. V. VOEVODENKO and I. M. PANTELEEV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), Jan.-Feb. 1989, p. 159-164. In Russian. refs

A combined numerical method based on the consecutive calculation of flows near the blunt leading edge of a wing and at its center is proposed for calculating supersonic flow of an ideal gas past a wing with a supersonic blunt leading edge. Flow parameters near the center of the wing are calculated on the basis of the plane flow law. Equations of motion for both regions are integrated numerically using Godunov's method. The results obtained are analyzed to evaluate the applicability of the combined method. V.L.

A89-35433
EFFECT OF THE ASYMMETRY OF BOUNDARY CONDITIONS ON BOUNDARY LAYER FLOW NEAR A CONE AT ANGLE OF ATTACK [O VLIIANII NESIMMETRII GRANICHNYKH USLOVII NA TECHENIE V POGRANICHNOM SLOE OKOLO KONUSA POD UGLOM ATAKI]
E. S. KORNIENKO and V. M. SHUCHINOV Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), Jan.-Feb. 1989, p. 173-176. In Russian. refs

The effect of the asymmetry of viscous flow past a cone is investigated for various values of the phase shift. Three-dimensional flow past a cone at angle of attack is calculated on the basis of the finite difference solution of the boundary layer equation. It is found that the presence of phase shifts may lead to the nonsymmetric distribution of enthalpy and injection and also to the hysteresis of the heat flux and friction force. Examples of calculations of laminar flow past a cone are presented. V.L.

A89-35434
TURBULIZATION OF A HIGH-VELOCITY BOUNDARY LAYER BY A PROJECTION [TURBULIZATSIIA VYSOKOSKOROSTNOGO POGRANICHNOGO SLOIA VYSTUPOM]
V. IA. KISELEV and V. I. LYSENKO Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), Jan.-Feb. 1989, p. 176-179. In Russian.

The turbulization of a boundary layer by a projection is investigated experimentally at Mach numbers greater than 5 using a nitrogen wind tunnel. It is found that even a high-velocity (very stable) boundary layer on a plate can be turbulized by means of a projection. As the height of the projection is increased, the position of the laminar-turbulent transition approaches that of the turbulizer. A further increase in the projection height leads to nonviscous boundary layer separation and to a noticeable flow restructuring. V.L.

A89-35435
THIN AXISYMMETRIC CAVERNS IN SUPERSONIC FLOW [TONKIE OSESIMMETRICHNYE KAVERNY V SVERKHZVUKOVOM POTOKE]
A. D. VASIN Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281), Jan.-Feb. 1989, p. 179-181. In Russian. refs

An integro-differential equation for the profile of a cavern in supersonic flow is obtained in the context of thin body theory. An analytical expression is obtained which relates cavern elongation to the cavitation and Mach numbers. As the cavitation number decreases, the effect of compressibility on cavern elongation becomes insignificant. V.L.

A89-35450
A METHOD FOR CALCULATING POTENTIAL TRANSONIC FLOWS IN TURBOMACHINERY CASCADES [METOD RASCHETA POTENTSIAL'NYKH TRANSZVUKOVYKH TECHENII V RESHETKAKH TURBOMASHIN]
P. M. BYVAL'TSEV and M. IA. IVANOV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 29, March 1989, p. 447-459. In Russian. refs

A fast method has been developed for calculating stationary subsonic, transonic, and supersonic potential flows in plane cascades and in cascades located on a rotation surface in a variable-thickness layer. The method implements a version of the approximate factorization method which retains second-order accuracy in the supersonic regions of the flow. The method is based on the numerical integration of the complete equation for the velocity potential written in divergent form in arbitrary curvilinear coordinates. The advantages of this approach over the commonly used versions of the approach that uses the method of artificial compressibility in the supersonic regions are demonstrated. V.L.

A89-35481
SUPERSONIC FLOW PAST CARET WINGS AND ELEMENTS OF STAR-SHAPED BODIES AT ANGLES OF ATTACK AND BANK [SVERKHZVUKOVOE OBTEKANIE LAMBDA-KRYL'EV I ELEMENTOV ZVEZDOOBRAZNYKH TEL PRI UGLAKH ATAKI I KRENA]
O. N. IVANOV and A. I. SHVETS PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Jan.-Feb. 1989, p. 81-87. In Russian. refs

Experimental results are reported on supersonic flow past caret wings at angles of attack and bank. The results cover flow characteristics for a wide range of anhedral angles (the caret angle between the windward planes of the wing), with both a curved shock wave and a system of shocks between the wings, corresponding to Mach and regular interactions. For large anhedral angles (150-180 deg), the flow schemes studied correspond to nonsymmetric flow past aircraft with caret wings; for small anhedral angles (less than 90 deg), they correspond to flow past an element of a star-shaped body. V.L.

A89-35495
POTENTIAL MODELS OF TRANSONIC FLOWS [O POTENTSIAL'NYKH MODELIAKH TRANSZVUKOVYKH TECHENII]
IU. B. LIFSHITS and A. A. SHAGAEV (Tsentral'nyi Aerogidrodinamicheskii Institut, Moscow, USSR) Akademiia Nauk SSSR, Doklady (ISSN 0002-3264), vol. 304, no. 6, 1989, p. 1315-1319. In Russian. refs

The paper considers the development of potential models for transonic flows, where the Zhukovskii-Chaplygin condition guarantees uniqueness of the solution. The proposed method is used to calculate transonic flow past wing profiles. In particular, the pressure-coefficient distribution is shown for the NACA 0012 profile at a freestream Mach number of 0.8 and an angle of attack of 1.25 deg. B.J.

A89-35994
BOUND VORTEX BOUNDARY LAYER CONTROL WITH APPLICATION TO V/STOL AIRPLANES
V. J. MODI, F. MOKHTARIAN (British Columbia, University, Vancouver, Canada), T. YOKOMIZO, G. OHTA, and T. OINUMA (Kanto Gakuin University, Yokohama, Japan) (IUTAM, Science Council of Japan, Architectural Institute of Japan, et al., Symposium on Fundamental Aspects of Vortex Motion, Tokyo, Japan, Aug. 31-Sept. 4, 1987) Fluid Dynamics Research (ISSN 0169-5983), vol. 3, no. 1-4, Sept. 1988, p. 225-230.
(Contract NSERC-A-2181)

The fluid dynamics of airfoils with rotating cylinder boundary layer control is studied using a numerical surface singularity approach incorporating separated flow and wall confinement effects. A finite-difference boundary layer scheme is used to account for viscous corrections. A comparison is made between numerical and experimental data on the pressure distribution and associated lift characteristics. K.K.

A89-35999
VORTEX BREAKDOWN AND ITS CONTROL ON DELTA WINGS
A. SCHMUECKER and K. GERSTEN (Bochum, Ruhr-Universitaet, Federal Republic of Germany) (IUTAM, Science Council of Japan, Architectural Institute of Japan, et al., Symposium on Fundamental Aspects of Vortex Motion, Tokyo, Japan, Aug. 31-Sept. 4, 1987) Fluid Dynamics Research (ISSN 0169-5983), vol. 3, no. 1-4, Sept. 1988, p. 268-272.

In order to investigate the breakdown of vortices generated by the leading edge of delta wings, LDA-measurements have been performed in the flow on the suction side of a delta wing of aspect ratio Lambda = 2. The measurements describe the growth of the vortex along the leading edge and reveal a certain radial structure upstream of the breakdown point. Moreover, they shed light on the mechanism responsible for the onset of vortex breakdown on the suction side of a wing. The occurrence of the breakdown phenomenon on a delta wing may be prevented or at least retarded by the use of spanwise blowing jets. The interaction of vortex and jets giving rise to these effects is discussed with the help of measured velocity profiles. Author

A89-36006
SOUND GENERATION AND FLOW INTERACTION OF VORTICES WITH AN AIRFOIL AND A FLAT PLATE IN TRANSONIC FLOW
G. E. A. MEIER, H.-M. LENT, and K. F. LOEHR (Max-Planck-Institut fuer Stroemungsforschung, Goettingen, Federal Republic of Germany) (IUTAM, Science Council of Japan, Architectural Institute of Japan, et al., Symposium on Fundamental Aspects of Vortex Motion, Tokyo, Japan, Aug. 31-Sept. 4, 1987) Fluid Dynamics Research (ISSN 0169-5983), vol. 3, no. 1-4, Sept. 1988, p. 344-348. refs

The mechanisms of sound generation and the kind of interaction of vortices with airfoils in an airflow are investigated. Experiments have been performed in stationary flow with vortices of a Karman vortex street and in a shock tube flow with a starting vortex of a lifting airfoil. Depending on the dimensions of vortices and airfoils, their distance, and the flow Mach numbers, different kinds and amplitudes of upstream propagating steep sound waves occur. Author

A89-36012
DETAILED MEASUREMENTS IN THE TRANSONIC VORTICAL FLOW OVER A DELTA WING
H. HORNUNG (DFVLR, Institut fuer experimentelle Stroemungsmechanik, Goettingen, Federal Republic of Germany) and A. ELSENAAR (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) (IUTAM, Science Council of Japan, Architectural Institute of Japan, et al., Symposium on Fundamental Aspects of Vortex Motion, Tokyo, Japan, Aug. 31-Sept. 4, 1987) Fluid Dynamics Research (ISSN 0169-5983), vol. 3, no. 1-4, Sept. 1988, p. 381-386. refs

Experimental results obtained in the Joint International Vortex Flow Experiment for Euler Code Validation are presented, which document surface and field information on compressible flow over a delta wing, with particular emphasis on the vortical flow on the

lee side. The results show that dissipative effects in Euler computations are concentrated at the wall, in the vortex sheet, in shock waves, and in the vortex core. They lead to significant total pressure losses that are almost independent of the numerical details of the method and of the same order as experimentally observed values. The validity of using Euler computations for such flows is discussed. I.S.

A89-36013
SOME CONSIDERATIONS ON LEADING EDGE VORTICES ON WINGS IN SUPERSONIC FLOW
ADRIANA NASTASE (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) (IUTAM, Science Council of Japan, Architectural Institute of Japan, et al., Symposium on Fundamental Aspects of Vortex Motion, Tokyo, Japan, Aug. 31-Sept. 4, 1987) Fluid Dynamics Research (ISSN 0169-5983), vol. 3, no. 1-4, Sept. 1988, p. 387-391. refs

This paper considers the determination of the shape, position, and intensity of leading-edge vortices on the lee side of the following wing models: a wedged delta wing fitted with fuselage, a double-wedged wing, and a wedged delta wing. These parameters are obtained by interpretation of skin friction lines and by exploration of the theoretical and experimental pressure coefficients on the surface of the these wing models in supersonic flow. It is shown that leading edge vortices have a great influence on the pressure distribution on the lee side of the wing surface in the vicinity of the leading edge of the wing, but have no influence on the lift and pitching moment coefficients of these wings on the pressure distribution on the wind side of the wing and on the central part of the lee side of the wing. I.S.

A89-36022#
NUMERICAL ANALYSIS OF THREE-DIMENSIONAL NON RIGID WINGS
THOMAS CHATZIKONSTANTINOU (Software und Beratung fuer die Segel- und Drachenkonstruktion, Berlin, Federal Republic of Germany) AIAA, Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989. 20 p.
(AIAA PAPER 89-0907)

This paper presents a numerical method for predicting the behavior of an elastic membrane wing under aerodynamic loading. Its shape cannot be found unless the pressure distribution is known and the pressure cannot be found unless the shape is known. It follows that both the aerodynamic and structural problems have to be solved simultaneously. Mathematically this leads to an integrodifferential equation. The equation can be solved numerically with a combined iterative finite-element/integral-equation method. The pressure is calculated using a vortex-lattice simulation of the steady potential flow and the shape is determined using a finite element representation of the structure. A sophisticated model for the numerical analysis of ram air wings is presented, measured values are compared to calculated values for one ram air wing. Author

N89-20092# National Center for Atmospheric Research, Boulder, CO. Atmospheric Technology Div.
POSITION ERROR CALIBRATION OF A PRESSURE SURVEY AIRCRAFT USING A TRAILING CONE
EDWARD N. BROWN Jul. 1988 37 p
(Contract NSF ATM-87-09659)
(PB88-250733; NCAR/TN-313-STR) Avail: NTIS HC A03/MF A01 CSCL 01A

A review is presented of the trailing cone development and testing, application procedures and the results of position error evaluation over a wide speed and altitude range. The position error of the NCAR Sabreliner determined by the trailing cone method is different from the error determined from earlier tower flights. Independent comparisons with pacer aircraft confirm the static pressure differences between the two position error functions. D-values during deceleration maneuvers at the pressure survey altitudes indicate the coefficients of the dynamic pressure terms of either correction function are valid and the versatility of the trailing cone method provides sufficient data to indicate the position error has no significant Mach number sensitivity in the medium to high subsonic range. The uncertainty or the largest expected error in the Sabreliner static pressure measurement after correction for position error is + or - 0.39mb. Author

N89-20093*# Boeing Commercial Airplane Co., Seattle, WA.
DEVELOPMENT AND APPLICATION OF A PROGRAM TO CALCULATE TRANSONIC FLOW AROUND AN OSCILLATING THREE-DIMENSIONAL WING USING FINITE DIFFERENCE PROCEDURES Final Report
WARREN H. WEATHERILL and F. EDWARD EHLERS Feb. 1989 91 p
(Contract NAS1-17977)
(NASA-CR-181744; NAS 1.26:181744; D6-54693) Avail: NTIS HC A05/MF A01 CSCL 01A

A finite difference method for solving the unsteady transonic flow about harmonically oscillating wings is investigated. The procedure is based on separating the velocity potential into steady and unsteady parts and linearizing the resulting unsteady differential equation for small disturbances. The differential equation for the unsteady potential is linear with spatially varying coefficients and with the time variable eliminated by assuming harmonic motion. Difference equations are derived for harmonic transonic flow to include a coordinate transformation for swept and tapered planforms. A pilot program is developed for three-dimensional planar lifting surface configurations (including thickness) for the CRAY-XMP at Boeing Commercial Airplanes and for the CYBER VPS-32 at the NASA Langley Research Center. An investigation is made of the effect of the location of the outer boundaries on accuracy for very small reduced frequencies. Finally, the pilot program is applied to the flutter analysis of a rectangular wing. Author

N89-20094*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SOME LOW-SPEED FLUTTER CHARACTERISTICS OF SIMPLE LOW-ASPECT-RATIO DELTA WING MODELS
ROBERT V. DOGGETT, JR. and DAVID L. SOISTMANN (Planning Research Corp., Hampton, VA.) Jan. 1989 11 p Presented at the 30th AIAA/ASME/AHS/ASC Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-4 Apr. 1989
(NASA-TM-101547; NAS 1.15:101547; AIAA-89-1325) Avail: NTIS HC A03/MF A01 CSCL 01A

Some results from a combined experimental and analytical study of the low-speed flutter characteristics of low-aspect-ratio delta wings are presented. Data are presented which show the effects of sweep angle on the flutter characteristics of some simple plate models of constant planform area. The range of sweep angles studied was from 30 to 72 degrees. In addition, flutter results are presented for two 30 deg-sweep clipped-delta wing models. Further, results are presented that show the effects of root clamping (percentage length of the root chord that is cantilevered) for a 45 deg-sweep delta wing. The experimental data are compared with analytical results obtained by using kernel function and doublet lattice subsonic unsteady lifting surface theories. Author

N89-20096 Leicester Univ. (England).
HIGH REYNOLDS NUMBER INCOMPRESSIBLE FLOW SIMULATION ABOUT PARACHUTE CANOPIES AND SIMILAR BLUFF BODIES Ph.D. Thesis
YAACOV I. FRUCHT 1987 219 p
Avail: Univ. Microfilms Order No. BRD-82605

A model for the flow around bluff bodies was developed. It is applied to an investigation of parachute canopy aerodynamic characteristics. The model assumes an axisymmetric incompressible high Reynolds number flow, applicable to the calculation of aerodynamic characteristics at zero angle of attack. The flow is assumed to separate from the canopy at its hemline. The vorticity is carried downstream, forming a free shear layer. In the flow field vorticity is confined to the shear layer, outside it the flow is irrotational. A velocity potential can be defined in the fluid field. The canopy surface is replaced by a vortex ring panel lattice. Each panel contains a circular bound vortex ring which is located

at one quarter panel length. For each panel the flow boundary conditions on the canopy surface are fulfilled along a control circle at three quarters of the panel length. In the vortex modelling of the separated wake a number of elements were introduced: improvement of the near wake simulation by accounting for the standing eddy on the canopy under surface; a simple method of calculating the newly created vortex ring strength and location; and reduction of the free parameters from two, the time step and the number of panels representing the canopy surface to one, i.e., the number of panels. Further model validation and implementation were suggested. Methods of model development for asymmetric canopy representation were discussed. Dissert. Abstr.

N89-20097 Old Dominion Univ., Norfolk, VA.
VISCOUS SHOCK LAYER ANALYSIS OF HYPERSONIC FLOWS OVER LONG SLENDER VEHICLES Ph.D. Thesis
KAM-PUI LEE 1988 222 p
Avail: Univ. Microfilms Order No. DA8823955

A method for solving the viscous shock layer equations for hypersonic flows over long slender bodies is presented. The governing equations are solved by employing a spatial marching implicit finite difference technique. The two first order equations, continuity and normal momentum, are solved simultaneously as a coupled set. This method yields a simple and computationally efficient technique. Flows past hyperboloids and sphere cones with body half angles of 5 to 35 deg are considered. The flow conditions included are from high Reynolds numbers at low altitudes to low Reynolds numbers at high altitudes. Detailed comparisons were made with other predictions and experimental data for slender body flows. The results show that the coupling between the continuity and normal momentum equations is essential and adequate to obtain stable and accurate solutions past long slender bodies. Both the Cebeci-Smith and Baldwin-Lomax turbulence models are found to be adequate for application to long slender bodies. Using the corrected slip models, the viscous shock layer predictions compare favorably with experimental data. Under chemical nonequilibrium conditions, the surface catalytic effects can influence the heat transfer. Dissert. Abstr.

N89-20098*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EVALUATION OF VSAERO IN PREDICTION OF AERODYNAMIC CHARACTERISTICS OF HELICOPTER HUB FAIRINGS
ALEXANDER LOUIE Feb. 1989 36 p
(NASA-TM-101048; A-88320; NAS 1.15:101048) Avail: NTIS HC A03/MF A01 CSCL 01A

A low-order panel code, VSAERO, was used to predict the aerodynamic characteristics of helicopter hub fairings. Since the simulation of this kind of bluff body by VSAERO was not documented before, the VSAERO solutions were correlated with experimental data to establish their validity. The validation process revealed that simulation of the aerodynamic environment around a hub fairing was sensitive to several modeling parameters. Some of these parameters are body and wake panels arrangement, streamwise and spanwise separation location, and the most prominent one-the wake modeling. Three wake models were used: regular wake, separated wake, and jet model. The regular wake is a wake with negligible thickness (thin wake). It is represented by a single vortex sheet. The separated wake and the jet model in the present application are wakes with finite thickness (thick wake). They consist of a vortex sheet enclosing a region of low-energy flow. The results obtained with the requlr wake were marginally acceptable for sharp-edged hub fairings. For all other cases under consideration, the jet model results correlated slightly better. The separated wake, which seemed to be the most appropriate model, caused the solution to diverge. While the regular wake was straight-forward to apply in simulations, the jet model was not. It requires the user to provide information about the doublet strength gradient on wake panels by guessing the efflux velocities at the wake shedding location. In summary, VSAERO neither predicts accurately the aerodynamic characteristics of helicopter hub fairings nor was cost effective. Author

N89-20099*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GEOMETRICAL AND STRUCTURAL PROPERTIES OF AN AEROELASTIC RESEARCH WING (ARW-2)
MAYNARD C. SANDFORD, DAVID A. SEIDEL, CLINTON V. ECKSTROM, and CHARLES V. SPAIN (PRC Kentron, Inc., Hampton, VA.) Washington Apr. 1989 40 p
(NASA-TM-4110; L-16545; NAS 1.15:4110) Avail: NTIS HC A03/MF A01 CSCL 01A

Transonic steady and unsteady pressure tests were conducted on a large elastic wing known as the DAST ARW-2 wing. The wing has a supercritical airfoil, an aspect ratio of 10.3, a leading edge sweepback angle of 28.8 deg and is equipped with two inboard and one outboard trailing edge control surfaces. The geometrical and structural characteristics are presented of this elastic wing, using a combination of measured and calculated data, to permit future analyst to compare the experimental surface pressure data with theoretical predictions. Author

N89-20100*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DOCUMENTATION OF TWO- AND THREE-DIMENSIONAL HYPERSONIC SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTION FLOWS
MARVIN I. KUSSOY (Eloret Corp., Sunnyvale, CA.) and CLIFFORD C. HORSTMAN Jan. 1989 26 p
(Contract NCC2-452)
(NASA-TM-101075; A-89048; NAS 1.15:101075) Avail: NTIS HC A03/MF A01 CSCL 01A

Experimental data for a series of two- and three-dimensional shock wave/turbulent boundary layer interaction flows at Mach 7 are presented. Test bodies, composed of simple geometric shapes, were designed to generate flows with varying degrees of pressure gradient, boundary-layer separation, and turning angle. The data include surface-pressure and heat-transfer distributions as well as limited mean-flow-field surveys in both the undisturbed and the interaction regimes. The data are presented in a convenient form for use in validating existing or future computational models of these generic hypersonic flows. Author

N89-20101*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A CELL-VERTEX MULTIGRID METHOD FOR THE NAVIER-STOKES EQUATIONS
R. RADESPIEL Jan. 1989 41 p
(NASA-TM-101557; NAS 1.15:101557) Avail: NTIS HC A03/MF A01 CSCL 01A

A cell-vertex scheme for the Navier-Stokes equations, which is based on central difference approximations and Runge-Kutta time stepping, is described. Using local time stepping, implicit residual smoothing, a multigrid method, and carefully controlled artificial dissipative terms, very good convergence rates are obtained for a wide range of two- and three-dimensional flows over airfoils and wings. The accuracy of the code is examined by grid refinement studies and comparison with experimental data. For an accurate prediction of turbulent flows with strong separations, a modified version of the nonequilibrium turbulence model of Johnson and King is introduced, which is well suited for an implementation into three-dimensional Navier-Stokes codes. It is shown that the solutions for three-dimensional flows with strong separations can be dramatically improved, when a nonequilibrium model of turbulence is used. Author

N89-20102# National Aerospace Lab., Amsterdam (Netherlands). Flight Dynamics Div.
OBSERVED REYNOLDS NUMBER EFFECTS ON AIRFOILS AND HIGH ASPECT RATIO WINGS AT TRANSONIC FLOW CONDITIONS
A. ELSENAAR 1 Feb. 1988 49 p Presented at the AGARD Special Course on Boundary Layer Simulation Methodology in

Transonic Wind Tunnel Testing, Brussels, Belgium and Tullahoma, 1988
(NLR-MP-88006-U; ETN-89-94055) Avail: NTIS HC A03/MF A01

Variation of airfoil and high aspect ratio wing aerodynamic characteristics (lift, pitching moment, drag, drag divergence, and buffet boundaries) as a function of Reynolds number is discussed. Examples related to drag, maximum lift, and pitching moment show that tests with free transition behave qualitatively different from flows with mostly turbulent boundary layer development (whether caused by natural transition close to the leading edge or by artificial means such as fixation). Free transition results can even be very misleading for flight conditions. For Reynolds number effects observed on configurations with fully turbulent boundary layer flow, a distinction between direct Reynolds number effects (resulting from changes in boundary layer development) and indirect Reynolds number effects (that appear as changes in pressure distribution) is made. The question of how relevant two-dimensional flows are to high aspect ratio wings is addressed. It is argued that certain conditions must be met before one can speak of a good correspondence between two- and three-dimensional flows. The utility of wind tunnel tests for flight prediction is reviewed. ESA

N89-20103# Institut Franco-Allemand de Recherches, Saint-Louis (France).
BASE FLOW INVESTIGATION BEHIND AXI-AND NON-AXISYMMETRIC BLUNT BODIES
C. BERNER 10 Dec. 1987 13 p Presented at ICALEO '87 - 6th International Congress on Application of Lasers and Electro-Optics, San Diego, CA, 8-12 Nov., 1987
(ISL-CO-246/87; ETN-89-94112) Avail: NTIS HC A03/MF A01

Experimental investigations of the flow field in the near-wake of blunt afterbodies are presented. Measurements were performed by a two- or three-dimensional frequency shifted laser Doppler velocimeter. Experiments were conducted in a blowdown type annular nozzle whose Mach number variation ranged between 0.2 and 0.9. Models consist of a cylindrical afterbody, and a conical and a triangular boattail. Results include mean velocities and the corresponding mean square velocity fluctuations. They show interesting features of the mean flow field and give accurate information about afterbody flows like local flow direction, size and shape of the recirculating regions, rear stagnation point location, and the differences in flow structure. ESA

N89-20105# Minnesota Univ., Minneapolis. Dept. of Aerospace Engineering and Mechanics.
AERODYNAMICS OF TWO-DIMENSIONAL SLOTTED BLUFF BODIES
F. TAKAHASHI and H. HIGUCHI 30 Apr. 1988 131 p Prepared for Sandia National Labs., Albuquerque, NM
(Contract DE-AC04-76DP-00789)
(DE89-007288; SAND-88-7151) Avail: NTIS HC A07/MF A01

Aerodynamic characteristics of two-dimensional, slotted bluff bodies were experimentally investigated. Flow visualizations, base pressure measurements, mean velocity vector measurements, and drag force measurements were conducted to analyze effects of spacing ratio (i.e., porosity), curvature, and vent. Low porosity model configurations produced stable near-wake patterns with enhanced vortex sheddings of overall wake formations. Model curvature reduced drag forces and weakened the vortex sheddings. Stabilizing effect of curvature on the near-wake patterns was also found. A vent combined with large model curvature was found to control drag force effectively, as well as suppressing vortex sheddings. DOE

N89-20920*# Sverdrup Technology, Inc., Cleveland, OH.
SUBHARMONIC AND FUNDAMENTAL HIGH AMPLITUDE EXCITATION OF AN AXISYMMETRIC JET
GANESH RAMAN and EDWARD J. RICE (National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.) Mar. 1989 28 p Presented at the 2nd Shear Flow Conference, Tempe, AZ, 13-16 Mar. 1989; sponsored in part by AIAA
(NASA-TM-101946; E-4595; NAS 1.15:101946; AIAA-89-0993)
Avail: NTIS HC A03/MF A01 CSCL 01A

A circular jet was excited simultaneously by two different harmonically related tones. Data for three pairs of Strouhal numbers (St(D) = f*D/U (sub j) = 0.2 and 0.4, 0.3 and 0.6, 0.4 and 0.8). For each case the initial phase difference between the two waves was varied in steps of 45 deg, for one full cycle and the level of the fundamental and subharmonic forcing were varied independently over the range of 0.1 to 7 percent of the jet exit velocity. Our initial findings concurred with published findings, such as a critical level of the fundamental is required for subharmonic augmentation, the initial phase difference is critical in determining whether the subharmonic is augmented or suppressed. The detailed documentation of several aspects of this phenomenon all measured in one and the same experimental facility in a controlled manner, bring out several important points that eluded previous researchers: (1) At high amplitudes of the fundamental and subharmonic forcing levels the subharmonic augmentation is independent of the initial phase difference. (2) Contrary to the earlier belief that stable pairing could be produced only with an initial laminar boundary layer, the present work shows that by the two-frequency excitation method this phenomenon can be induced over a range of conditions for a jet with an initially turbulent boundary layer. (3) It is seen that two-frequency excitation is indeed more effective than single frequency excitation in jet mixing enhancement. Higher spreading rates seem to go along with higher subharmonic levels. Author

N89-20921*# Sverdrup Technology, Inc., Cleveland, OH.
COMPARISON OF 3D COMPUTATION AND EXPERIMENT FOR NON-AXISYMMETRIC NOZZLES Final Report
H. LAI and E. NELSON Feb. 1989 12 p Presented at the 27th Aerospace Sciences Meeting, Reno, NV, 9-12 Jan. 1989; sponsored in part by AIAA
(Contract NAS3-24105; NAS3-25266)
(NASA-CR-182245; E-4574; NAS 1.26:182245; AIAA-89-0007)
Avail: NTIS HC A03/MF A01 CSCL 01A

Three dimensional solutions of a single expansion ramp nozzle are computed with the existing PARC computer code by solving the full Navier-Stokes equations. The computations are performed to simulate the non-axisymmetric nozzle flowfield in both the internal/external expansion regions and the exhaust plume in a quiescent ambient environment. Two different configurations of the nozzle at a pressure ratio NPR = 10 are examined. Numerical results of laminar flows are presented, and the wall pressure distributions are compared with the experimental data. Author

N89-20922*# Boeing Advanced Systems Co., Seattle, WA.
ADDITIONAL DEVELOPMENT OF THE XTRAN3S COMPUTER PROGRAM Final Report
C. J. BORLAND Jan. 1989 98 p
(Contract NAS1-17864)
(NASA-CR-181743; NAS 1.26:181743) Avail: NTIS HC A05/MF A01 CSCL 01A

Additional developments and enhancements to the XTRAN3S computer program, a code for calculation of steady and unsteady aerodynamics, and associated aeroelastic solutions, for 3-D wings in the transonic flow regime are described. Algorithm improvements for the XTRAN3S program were provided including an implicit finite difference scheme to enhance the allowable time step and vectorization for improved computational efficiency. The code was modified to treat configurations with a fuselage, multiple stores/nacelles/pylons, and winglets. Computer program changes (updates) for error corrections and updates for version control are provided. Author

N89-20923 California Univ., Los Angeles.
TRANSVERSE JETS IN COMPRESSIBLE CROSSFLOWS Ph.D. Thesis
STEPHEN DOUGLAS HEISTER 1988 211 p
Avail: Univ. Microfilms Order No. DA8826010

The deflection and mixing of both gaseous and liquid jets in compressible crossflows are discussed. For gaseous jets, the jet

cross-section is modeled as a compressible vortex pair which results from viscous forces at the periphery of the jet. The behavior of the vortex pair is then combined with mass and momentum balances along the axis of the jet to form a model which describes the trajectory and mixing of the injected fluid. In the case of a supersonic crossflow, a numerical technique is used to solve the inviscid outer flow and the position of the bow shock which envelopes the jet. This solution was combined with a liquid jet model developed by T.T. Nguyen to calculate liquid jet trajectories and the location of jet breakup. The solution was also combined with the compressible vortex pair of solution to generate trajectories of gaseous jets in supersonic crossflows. Dissert. Abstr.

N89-20924 Stanford Univ., CA.
NUMERICAL SIMULATION OF THE FLOW FIELD OVER DELTA WINGS WITH LEADING EDGE BLOWING Ph.D. Thesis
DAVID T. YEH 1988 131 p
Avail: Univ. Microfilms Order No. DA8826271

The vortical flow over a delta wing contributes an important part of the lift - the so-called nonlinear vortex lift. Controlling this vortical flow with its favorable influence would enhance the maneuverability and control of the aircraft. Several experiments have revealed that span-wise and tangential leading edge blowing can be applied as a means of controlling the position and strength of the leading edge vortices. The present research studies these effects by numerical solution of the three-dimensional Navier-Stokes equations. The leading edge jet is simulated by defining a permeable boundary, corresponding to the jet slot, where suitable boundary conditions are implemented. Numerical results are shown to compare favorably with experimental measurements. It is found that the use of spanwise leading edge blowing at moderate angle of attack magnifies the size and strength of the leading edge vortices, and moves the vortex cores outboard and upward. The increase in lift primarily comes from the greater nonlinear vortex lift. However, spanwise blowing causes earlier vortex breakdown, thus decreasing the stall angle. The effects of tangential blowing at low to moderate angles of attack tend to reduce the pressure peaks associated with leading edge vortices and to increase the suction peak around the leading edge. Dissert. Abstr.

N89-20925*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSONIC SYMPOSIUM: THEORY, APPLICATION, AND EXPERIMENT, VOLUME 1, PART 1
JEROME T. FOUGHNER, JR., comp. Mar. 1989 416 p Symposium held in Hampton, VA, 19-21 Apr. 1988; sponsored by NASA, Washington Original contains color illustrations
(NASA-CP-3020-VOL-1-PT-1; L-16501-VOL-1-PT-1; NAS 1.55:3020-VOL-1-PT-1) Avail: NTIS HC A18/MF A01 CSCL 01A

Topics addressed include: wind tunnel and flight experiments; computational fluid dynamics (CFD) applications, industry overviews; and inviscid methods and grid generations.

N89-20926*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIRFRAME/PROPULSION INTEGRATION CHARACTERISTICS AT TRANSONIC SPEEDS
WILLIAM P. HENDERSON and BOBBY L. BERRIER *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 1-31 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

The aerodynamic characteristics for both single and twin-engine high-performance aircraft are significantly affected by shock induced flow interactions as well as other local flow interference effects which usually occur at transonic speeds. These adverse interactions can not only cause high drag, but also cause unusual aerodynamic loadings and/or severe stability and control problems. Many programs are under way to not only develop method for reducing the adverse effects, but also to develop an understanding of the basic flow conditions which are the primary contributors. It is anticipated that these programs will result in technologies which can reduce the aircraft cruise drag through improved integration as well as increase aircraft maneuverability through the application of thrust vectoring. Some of the primary integration problems for twin-engine aircraft at transonic speeds are identified, and several methods are demonstrated for reducing or eliminating the undersirable characteristics, while enhancing configuration effectiveness. Author

N89-20927*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FLIGHT RESEARCH AND TESTING
TERRILL W. PUTNAM and THEODORE G. AYERS *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 33-59 Mar. 1989 Previously announced as N88-26361
Avail: NTIS HC A18/MF A01 CSCL 01A

Flight research and testing form a critical link in the aeronautic research and development chain. Brilliant concepts, elegant theories, and even sophisticated ground tests of flight vehicles are not sufficient to prove beyond a doubt that an unproven aeronautical concept will actually perform as predicted. Flight research and testing provide the ultimate proof that an idea or concept performs as expected. Ever since the Wright brothers, flight research and testing were the crucible in which aeronautical concepts were advanced and proven to the point that engineers and companies are willing to stake their future to produce and design aircraft. This is still true today, as shown by the development of the experimental X-30 aerospace plane. The Dryden Flight Research Center (Ames-Dryden) continues to be involved in a number of flight research programs that require understanding and characterization of the total airplane in all the aeronautical disciplines, for example the X-29. Other programs such as the F-14 variable-sweep transition flight experiment have focused on a single concept or discipline. Ames-Dryden also continues to conduct flight and ground based experiments to improve and expand the ability to test and evaluate advanced aeronautical concepts. A review of significant aeronautical flight research programs and experiments is presented to illustrate both the progress being made and the challenges to come. Author

N89-20928*# High Technology Corp., Hampton, VA.
SHOCK-BOUNDARY-LAYER INTERACTION IN FLIGHT
ARILD BERTELRUD *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 61-77 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

A brief survey is given on the study of transonic shock/boundary layer effects in flight. Then the possibility of alleviating the adverse shock effects through passive shock control is discussed. A Swedish flight experiment on a swept wing attack aircraft is used to demonstrate how it is possible to reduce the extent of separated flow and increase the drag-rise Mach number significantly using a moderate amount of perforation of the surface. Author

N89-20929*# Boeing Commercial Airplane Co., Seattle, WA. Computational Fluid Dynamics Lab.
TRANSONIC CFD APPLICATIONS AT BOEING
E. N. TINOCO *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 79-107 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

The use of computational methods for three dimensional transonic flow design and analysis at the Boeing Company is presented. A range of computational tools consisting of production tools for every day use by project engineers, expert user tools for special applications by computational researchers, and an emerging tool which may see considerable use in the near future are described. These methods include full potential and Euler solvers, some coupled to three dimensional boundary layer analysis methods, for transonic flow analysis about nacelle, wing-body, wing-body-strut-nacelle, and complete aircraft configurations. As the examples presented show, such a toolbox of codes is necessary

for the variety of applications typical of an industrial environment. Such a toolbox of codes makes possible aerodynamic advances not previously achievable in a timely manner, if at all. Author

N89-20930*# General Dynamics Corp., Fort Worth, TX.
THE APPLICATION OF CFD FOR MILITARY AIRCRAFT DESIGN AT TRANSONIC SPEEDS
C. W. SMITH, W. W. BRAYMEN, I. C. BHATELEY, and W. K. LONDENBERG *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 109-132 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

Numerous computational fluid dynamics (CFD) codes are available that solve any of several variations of the transonic flow equations from small disturbance to full Navier-Stokes. The design philosophy at General Dynamics Fort Worth Division involves use of all these levels of codes, depending on the stage of configuration development. Throughout this process, drag calculation is a central issue. An overview is provided for several transonic codes and representative test-to-theory comparisons for fighter-type configurations are presented. Correlations are shown for lift, drag, pitching moment, and pressure distributions. The future of applied CFD is also discussed, including the important task of code validation. With the progress being made in code development and the continued evolution in computer hardware, the routine application of these codes for increasingly more complex geometries and flow conditions seems apparent. Author

N89-20931*# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems.
APPLIED TRANSONICS AT GRUMMAN
W. H. DAVIS *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 133-152 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

A review of several applications of Computational Fluid Dynamics (CFD) to various aspects of aerodynamic design recently carried out at Grumman is presented. The emphasis is placed on project-oriented applications where the ease of use of the methods and short start-to-completion times are required. Applications cover transonic wing design/optimization, wing mounted stores load prediction, transonic buffet alleviation, fuselage loads estimation, and compact offset diffuser design for advanced aircraft configurations. Computational methods employed include extended transonic small disturbance (automatic grid embedding) formulation for analysis/design/optimization and a thin layer Navier-Stokes formulation for both external and internal flow analyses. Author

N89-20932*# Lockheed Aeronautical Systems Co., Burbank, CA.
TRANSONICS AND FIGHTER AIRCRAFT: CHALLENGES AND OPPORTUNITIES FOR CFD
LUIS R. MIRANDA *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 153-173 Mar. 1989 Original document contains color illustrations
Avail: NTIS HC A18/MF A01 CSCL 01A

The application of computational fluid dynamics (CFD) to fighter aircraft design and development is discussed. Methodology requirements for the aerodynamic design of fighter aircraft are briefly reviewed. The state-of-the-art of computational methods for transonic flows in the light of these requirements is assessed and the techniques found most adequate for the subject application are identified. Highlights from some proof-of-feasibility Euler and Navier-Stokes computations about a complete fighter aircraft configuration are presented. Finally, critical issues and opportunities for design application of CFD are discussed. Author

N89-20933*# Lockheed Aeronautical Systems Co., Marietta, GA. Advanced Flight Sciences Dept.
COMPUTATION OF AIRCRAFT COMPONENT FLOW FIELDS AT TRANSONIC MACH NUMBERS USING A THREE-DIMENSIONAL NAVIER-STOKES ALGORITHM
GEORGE D. SHREWSBURY, JOSEPH VADYAK, DAVID M. SCHUSTER, and MARILYN J. SMITH *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 175-194 Mar. 1989 Original document contains color illustrations
Avail: NTIS HC A18/MF A01 CSCL 01A

A computer analysis was developed for calculating steady (or unsteady) three-dimensional aircraft component flow fields. This algorithm, called ENS3D, can compute the flow field for the following configurations: diffuser duct/thrust nozzle, isolated wing, isolated fuselage, wing/fuselage with or without integrated inlet and exhaust, nacelle/inlet, nacelle (fuselage) afterbody/exhaust jet, complete transport engine installation, and multicomponent configurations using zonal grid generation technique. Solutions can be obtained for subsonic, transonic, or hypersonic freestream speeds. The algorithm can solve either the Euler equations for inviscid flow, the thin shear layer Navier-Stokes equations for viscous flow, or the full Navier-Stokes equations for viscous flow. The flow field solution is determined on a body-fitted computational grid. A fully-implicit alternating direction implicit method is employed for the solution of the finite difference equations. For viscous computations, either a two layer eddy-viscosity turbulence model or the k-epsilon two equation transport model can be used to achieve mathematical closure. Author

N89-20934*# Rockwell International Corp., Los Angeles, CA. Aircraft Operations.
TRANSONIC AERODYNAMIC DESIGN EXPERIENCE
E. BONNER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 195-216 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

Advancements have occurred in transonic numerical simulation that place aerodynamic performance design into a relatively well developed status. Efficient broad band operating characteristics can be reliably developed at the conceptual design level. Recent aeroelastic and separated flow simulation results indicate that systematic consideration of an increased range of design problems appears promising. This emerging capability addresses static and dynamic structural/aerodynamic coupling and nonlinearities associated with viscous dominated flows. Author

N89-20935*# Michigan Univ., Ann Arbor.
EULER SOLVERS FOR TRANSONIC APPLICATIONS
BRAM VANLEER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 217-230 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

The 1980s may well be called the Euler era of applied aerodynamics. Computer codes based on discrete approximations of the Euler equations are now routinely used to obtain solutions of transonic flow problems in which the effects of entropy and vorticity production are significant. Such codes can even predict separation from a sharp edge, owing to the inclusion of artificial dissipation, intended to lend numerical stability to the calculation but at the same time enforcing the Kutta condition. One effect not correctly predictable by Euler codes is the separation from a smooth surface, and neither is viscous drag; for these some form of the Navier-Stokes equation is needed. It, therefore, comes as no surprise to observe that the Navier-Stokes has already begun before Euler solutions were fully exploited. Moreover, most numerical developments for the Euler equations are now constrained by the requirement that the techniques introduced, notably artificial dissipation, must not interfere with the new physics added when going from an Euler to a full Navier-Stokes approximation. In order to appreciate the contributions of Euler solvers to the understanding of transonic aerodynamics, it is useful to review the components of these computational tools. Space discretization, time- or pseudo-time marching and boundary procedures, the essential constituents are discussed. The subject of grid generation and grid adaptation to the solution are touched upon only where relevant. A list of unanswered questions and an outlook for the future are covered. Author

N89-20936*# Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering.
AN EMBEDDED MESH PROCEDURE FOR LEADING-EDGE VORTEX FLOWS
KENNETH G. POWELL and EARLL M. MURMAN (Massachusetts Inst. of Tech., Cambridge.) *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 231-259 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

A cell-vertex scheme is outlined for solving the flow about a delta wing with M (sub infinity) is greater than 1. Embedded regions of mesh refinement allow solutions to be obtained which have much higher resolution than those achieved to date. Effects of mesh refinement and artificial viscosity on the solutions are studied, to determine at what point leading-edge vortex solutions are grid-converged. A macroscale and a microscale for the size of the vortex are defined, and it is shown that the macroscale (which includes the wing surface properties) is converged on a moderately refined grid, while the microscale is very sensitive to grid spacing. The level of numerical diffusion in the core of the vortex is found to be substantial. Comparisons with the experiment are made for two cases which have transonic cross-flow velocities. Author

N89-20937*# Michigan Univ., Ann Arbor.
ASYMPTOTIC METHODS FOR INTERNAL TRANSONIC FLOWS
T. C. ADAMSON, JR. and A. F. MESSITER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 261-291 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

For many internal transonic flows of practical interest, some of the relevant nondimensional parameters typically are small enough that a perturbation scheme can be expected to give a useful level of numerical accuracy. A variety of steady and unsteady transonic channel and cascade flows is studied with the help of systematic perturbation methods which take advantage of this fact. Asymptotic representations are constructed for small changes in channel cross-section area, small flow deflection angles, small differences between the flow velocity and the sound speed, small amplitudes of imposed oscillations, and small reduced frequencies. Inside a channel the flow is nearly one-dimensional except in thin regions immediately downstream of a shock wave, at the channel entrance and exit, and near the channel throat. A study of two-dimensional cascade flow is extended to include a description of three-dimensional compressor-rotor flow which leads to analytical results except in thin edge regions which require numerical solution. For unsteady flow the qualitative nature of the shock-wave motion in a channel depends strongly on the orders of magnitude of the frequency and amplitude of impressed wall oscillations or fluctuations in back pressure. One example of supersonic flow is considered, for a channel with length large compared to its width, including the effect of separation bubbles and the possibility of self-sustained oscillations. The effect of viscosity on a weak shock wave in a channel is discussed. Author

N89-20938*# Rensselaer Polytechnic Inst., Troy, NY.
WAVE DRAG DUE TO LIFT FOR TRANSONIC AIRPLANES
JULIAN D. COLE and NORMAN D. MALMUTH *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 293-308 Mar. 1989 Sponsored in part by Rockwell North American Aircraft
(Contract AF-AFOSR-0037-88)
Avail: NTIS HC A18/MF A01 CSCL 01A

Lift dominated pointed aircraft configurations are considered in the transonic range. These are treated as lifting wings of zero thickness with an aspect ratio of order one. An inner expansion which starts as Jones' theory is matched to a nonlinear outer transonic theory as in Barnwell's earlier work. Expressions for the wave drag due to the equivalent body are derived. Some examples of numerical calculations for different configurations are presented. Author

N89-20939*# California Univ., Davis.
VECTOR POTENTIAL METHODS
M. HAFEZ *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 309-339 Mar. 1989
Avail: NTIS HC A18/MF A01 CSCL 01A

Vector potential and related methods, for the simulation of both inviscid and viscous flows over aerodynamic configurations, are briefly reviewed. The advantages and disadvantages of several formulations are discussed and alternate strategies are recommended. Scalar potential, modified potential, alternate formulations of Euler equations, least-squares formulation, variational principles, iterative techniques and related methods, and viscous flow simulation are discussed. Author

N89-20940*# Princeton Univ., NJ.
DEVELOPMENTS AND TRENDS IN THREE-DIMENSIONAL MESH GENERATION
TIMOTHY J. BAKER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 341-376 Mar. 1989 Original document contains color illustrations
Avail: NTIS HC A18/MF A01 CSCL 01A

An intense research effort over the last few years has produced several competing and apparently diverse methods for generating meshes. Recent progress is reviewed and the central themes are emphasized which form a solid foundation for future developments in mesh generation. Author

N89-20941*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GENERATION OF UNSTRUCTURED GRIDS AND EULER SOLUTIONS FOR COMPLEX GEOMETRIES
RAINALD LOEHNER, PARESH PARIKH (Vigyan Research Associates, Inc., Hampton, VA.), and MANUEL D. SALAS *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 1 p 377-408 Mar. 1989 Prepared in cooperation with Naval Research Lab., Washington, DC
Avail: NTIS HC A18/MF A01 CSCL 01A

Algorithms are described for the generation and adaptation of unstructured grids in two and three dimensions, as well as Euler solvers for unstructured grids. The main purpose is to demonstrate how unstructured grids may be employed advantageously for the economic simulation of both geometrically as well as physically complex flow fields. Author

N89-20942*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSONIC SYMPOSIUM: THEORY, APPLICATION, AND EXPERIMENT, VOLUME 1, PART 2
JEROME T. FOUGHNER, JR., comp. Mar. 1989 511 p Symposium held in Hampton, VA, 19-21 Apr.1988; sponsored by NASA, Washington Original contains color illustrations
(NASA-CP-3020-VOL-1-PT-2; L-16501-VOL-1-PT-2; NAS 1.55:3020-VOL-1-PT-2) Avail: NTIS HC A22/MF A01 CSCL 01A

In order to assess the state of the art in transonic flow disciplines and to glimpse at future directions, NASA-Langley held a Transonic Symposium. Emphasis was placed on steady, three dimensional external, transonic flow and its simulation, both numerically and experimentally. The symposium included technical sessions on wind tunnel and flight experiments; computational fluid dynamic applications; inviscid methods and grid generation; viscous methods and boundary layer stability; and wind tunnel techniques and wall interference. This, being volume 1, is unclassified.

N89-20944*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AERODYNAMIC ANALYSIS OF THREE ADVANCED CONFIGURATIONS USING THE TRANAIR FULL-POTENTIAL CODE
M. D. MADSON, R. L. CARMICHAEL, and J. P. MENDOZA *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 437-452 Mar.

1989
Avail: NTIS HC A22/MF A01 CSCL 21E

Computational results are presented for three advanced configurations: the F-16A with wing tip missiles and under wing fuel tanks, the Oblique Wing Research Aircraft, and an Advanced Turboprop research model. These results were generated by the latest version of the TranAir full potential code, which solves for transonic flow over complex configurations. TranAir embeds a surface paneled geometry definition in a uniform rectangular flow field grid, thus avoiding the use of surface conforming grids, and decoupling the grid generation process from the definition of the configuration. The new version of the code locally refines the uniform grid near the surface of the geometry, based on local panel size and/or user input. This method distributes the flow field grid points much more efficiently than the previous version of the code, which solved for a grid that was uniform everywhere in the flow field. TranAir results are presented for the three configurations and are compared with wind tunnel data. Author

N89-20948*# McDonnell-Douglas Research Labs., Saint Louis, MO.
EULER/NAVIER-STOKES CALCULATIONS OF TRANSONIC FLOW PAST FIXED- AND ROTARY-WING AIRCRAFT CONFIGURATIONS
J. E. DEESE and R. K. AGARWAL *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 521-545 Mar. 1989 Original document contains color illustrations
Avail: NTIS HC A22/MF A01 CSCL 01A

Computational fluid dynamics has an increasingly important role in the design and analysis of aircraft as computer hardware becomes faster and algorithms become more efficient. Progress is being made in two directions: more complex and realistic configurations are being treated and algorithms based on higher approximations to the complete Navier-Stokes equations are being developed. The literature indicates that linear panel methods can model detailed, realistic aircraft geometries in flow regimes where this approximation is valid. As algorithms including higher approximations to the Navier-Stokes equations are developed, computer resource requirements increase rapidly. Generation of suitable grids become more difficult and the number of grid points required to resolve flow features of interest increases. Recently, the development of large vector computers has enabled researchers to attempt more complex geometries with Euler and Navier-Stokes algorithms. The results of calculations for transonic flow about a typical transport and fighter wing-body configuration using thin layer Navier-Stokes equations are described along with flow about helicopter rotor blades using both Euler/Navier-Stokes equations. Author

N89-20951*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TURBULENCE AND MODELING IN TRANSONIC FLOW
MORRIS W. RUBESIN and JOHN R. VIEGAS *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 581-610 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

A review is made of the performance of a variety of turbulence models in the evaluation of a particular well documented transonic flow. This is done to supplement a previous attempt to calibrate and verify transonic airfoil codes by including many more turbulence models than used in the earlier work and applying the calculations to an experiment that did not suffer from uncertainties in angle of attack and was free of wind tunnel interference. It is found from this work, as well as in the earlier study, that the Johnson-King turbulence model is superior for transonic flows over simple aerodynamic surfaces, including moderate separation. It is also shown that some field equation models with wall function boundary conditions can be competitive with it. Author

N89-20952*# Iowa State Univ. of Science and Technology, Ames. Dept. of Aerospace Engineering.
TURBULENT EDDY VISCOSITY MODELING IN TRANSONIC SHOCK/BOUNDARY-LAYER INTERACTIONS
G. R. INGER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 611-627 Mar. 1989 Previously announced in IAA as A88-40758
Avail: NTIS HC A22/MF A01 CSCL 01A

The treatment of turbulence effects on transonic shock/turbulent boundary layer interaction is addressed within the context of a triple deck approach valid for arbitrary practical Reynolds numbers between 1000 and 10 billion. The modeling of the eddy viscosity and basic turbulent boundary profile effects in each deck is examined in detail using Law-of-the-Wall/Law-of-the-Wake concepts as the foundation. Results of parametric studies showing how each of these turbulence model aspects influences typical interaction zone property distributions (wall pressure, displacement thickness and local skin friction) are presented and discussed. Author

N89-20953*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
STABILITY OF COMPRESSIBLE BOUNDARY LAYERS
ALI H. NAYFEH *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 629-689 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

The stability of compressible 2-D and 3-D boundary layers is reviewed. The stability of 2-D compressible flows differs from that of incompressible flows in two important features: There is more than one mode of instability contributing to the growth of disturbances in supersonic laminar boundary layers and the most unstable first mode wave is 3-D. Whereas viscosity has a destabilizing effect on incompressible flows, it is stabilizing for high supersonic Mach numbers. Whereas cooling stabilizes first mode waves, it destabilizes second mode waves. However, second order waves can be stabilized by suction and favorable pressure gradients. The influence of the nonparallelism on the spatial growth rate of disturbances is evaluated. The growth rate depends on the flow variable as well as the distance from the body. Floquet theory is used to investigate the subharmonic secondary instability. Author

N89-20954*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.
SECONDARY THREE-DIMENSIONAL INSTABILITY IN COMPRESSIBLE BOUNDARY LAYERS
NABIL M. EL-HADY *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 691-704 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

Three dimensional linear secondary instability theory is extended for compressible boundary layers on a flat plate in the presence of finite amplitude Tollmien-Schlichting waves. The focus is on principal parametric resonance responsible for strong growth of subharmonics in low disturbance environment. Author

N89-20956*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN LDA (LASER-DOPPLER ANEMOMETRY) INVESTIGATION OF THREE-DIMENSIONAL NORMAL SHOCK WAVE BOUNDARY-LAYER INTERACTIONS
R. M. CHRISS, W. R. HINGST, A. J. STRAZISAR, and T. G. KEITH, JR. (Toledo Univ., OH.) *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 741-764 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

Nonintrusive measurements were made of a normal shock wave/boundary layer interaction. Two dimensional measurements were made throughout the interaction region while 3-D measurements were made in the vicinity of the shock wave. The measurements were made in the corner of the test section of a

continuous supersonic wind tunnel in which a normal shock wave had been stabilized. Laser Doppler Anemometry, surface pressure measurement and flow visualization techniques were employed for two freestream Mach number test cases: 1.6 and 1.3. The former contained separated flow regions and a system of shock waves. The latter was found to be far less complicated. The results define the flow field structure in detail for each case. Author

N89-20958*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WALL INTERFERENCE ASSESSMENT AND CORRECTIONS
P. A. NEWMAN, W. B. KEMP, JR., and J. A. GARRIZ (Vigyan Research Associates, Inc., Hampton, VA.) *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 817-851 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

Wind tunnel wall interference assessment and correction (WIAC) concepts, applications, and typical results are discussed in terms of several nonlinear transonic codes and one panel method code developed for and being implemented at NASA-Langley. Contrasts between 2-D and 3-D transonic testing factors which affect WIAC procedures are illustrated using airfoil data from the 0.3 m Transonic Cryogenic Tunnel and Pathfinder 1 data from the National Transonic Facility. Initial results from the 3-D WIAC codes are encouraging; research on and implementation of WIAC concepts continue. Author

N89-20959*# Calspan Field Services, Inc., Arnold AFS, TN.
TWO-MEASURED VARIABLE METHOD FOR WALL INTERFERENCE ASSESSMENT/CORRECTION
C. F. LO and W. L. SICKLES *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 853-866 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

An iterative method for wall interference assessment and/or correction is presented for transonic flow conditions in wind tunnels equipped with two component velocity measurements on a single interface. The iterative method does not require modeling of the test article and tunnel wall boundary conditions. Analytical proof for the convergence and stability of the iterative method is shown in the subsonic flow regime. The numerical solutions are given for both 2-D and axisymmetrical cases at transonic speeds with the application of global Mach number correction. Author

N89-20960*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPARISON OF AIRFOIL RESULTS FROM AN ADAPTIVE WALL TEST SECTION AND A POROUS WALL TEST SECTION
RAYMOND E. MINECK *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 867-890 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01A

Two wind tunnel investigations were conducted to assess two different wall interference alleviation/correction techniques: adaptive test section walls and classical analytical corrections. The same airfoil model has been tested in the adaptive wall test section of the NASA-Langley 0.3 m Transonic Cryogenic Tunnel (TCT) and in the National Aeronautical Establishment (NAE) High Reynolds Number 2-D facility. The model has a 9 in. chord and a CAST 10-2/DOA 2 airfoil section. The 0.3 m TCT adaptive wall test section has four solid walls with flexible top and bottom walls. The NAE test section has porous top and bottom walls and solid side walls. The aerodynamic results corrected for top and bottom wall interference at Mach numbers from 0.3 to 0.8 at a Reynolds number of 10 by 1,000,000. Movement of the adaptive walls was used to alleviate the top and bottom wall interference in the test results from the NASA tunnel. Author

N89-20962# Maryland Univ., College Park. Dept. of Aerospace Engineering.
UNSTEADY FORCE CALCULATIONS ON CIRCULAR CYLINDERS AND ELLIPTICAL AIRFOILS WITH CIRCULATION CONTROL
VENKATRAMAN RAGHAVAN Dec. 1987 182 p
(UMAERO-87-37) Avail: NTIS HC A09/MF A01

A numerical method is developed to study the unsteady circulation control aerodynamics of two-dimensional airfoils. Two cases of unsteadiness in flow are considered. The first case is the unsteadiness arising from an unsteady, periodic freestream and the second is the unsteadiness due to unsteady blowing momentum. A simple solution for the potential flow is obtained using conformal mapping. The changes due to the presence of the separated wake region behind the airfoil is calculated by distributing a set of source panels in the wake region along the surface. The source strengths are determined by using the condition of constant pressure at the control points and that the velocity at the separation points must be zero. The unsteady potential flow is assumed to be a periodic variation of the steady potential flow, in phase with the periodic freestream. The boundary layer flow is calculated by solving the unsteady boundary layer equations using an implicit finite difference method. The flow due to the wall jet is calculated from quasi one-dimensional flow upto the slot on the surface and further downstream the mixing shear layer is computed numerically as part of the boundary layer solution. The finite difference method uses backward differences whenever reverse flow is encountered. The potential flow and the boundary layer and wall jet calculations are combined in an iterative procedure to get a converged solution for the entire flow field. The solution provides the velocity and pressure fields which is used to determined the lift and drag forces under given freestream and jet momentum conditions. The pressure distribution obtained from the potential flow is used to calcualte the lift and pressure drag forces. The wall shear data obtained from the boundary layer flow gives the skin friction drag.Satisfactory correlation of predicted results with experimental data is achieved for steady lift over circular cylinders as well as elliptic airfoils. Author

N89-20963*# Kansas Univ. Center for Research, Inc., Lawrence.
INVESTIGATION OF A FREE-TIP ROTOR CONFIGURATION FOR RESEARCH ON SPANWISE LIFE DISTRIBUTIONS AND WAKE VELOCITY SURVEYS OF A SEMI-SPAN WING WITH A DISCONTINUOUS TWIST Final Report
PAUL FORTIN and HIROYUKI KUMAGAI Apr. 1989 209 p
(Contract NCC2-175)
(NASA-CR-184948; NAS 1.26:184948) Avail: NTIS HC A10/MF A01 CSCL 01A

A wind tunnel test was conducted in the NASA Ames 7 x 10 Foot Wind Tunnel to investigate the lift distribution on a semi-span wing with a discontinuous change in spanwise twist. The semi-span wing had a tip with an adjustable pitch angle independent on the inboard section pitch angle simulating the free-tip rotor blade when its free-tip is at a deflected position. The spanwise lift distribution over the wing and the tip were measured and three component velocity surveys behind the wing were obtained with a three dimensional laser Doppler velocimeter (LV) with the wing at one angle of attack and the tip deflected at different pitch angles. A six component internal strain gage balance was also used to measure total forces and moments on the tip. The three dimensional lift was computed from the two dimensional life distributions obtained from the LV and from the strain gage balance. The results from both experimental methods are shown to be in agreement with predictions made by a steady, three dimensional panel code, VSAERO. Author

N89-20964*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THREE-DIMENSIONAL SINGULAR POINTS IN AERODYNAMICS
AYNUR UNAL Jan. 1988 19 p Prepared in cooperation with Army Aviation System s Command, Saint Louis, MO Submitted for publication
(NASA-TM-100045; A-88029; NAS 1.15:100045; AD-A197978; USAAVSCOM-TR-87-A-14) Avail: NTIS HC A03/MF A01 CSCL 01A

When three-dimensional separation occurs on a body immersed in a flow governed by the incompressible Navier-Stokes equations, the geometrical surfaces formed by the three vector fields (velocity, vorticity and the skin-friction) and a scalar field (pressure) become interrelated through topological maps containing their respective singular points and extremal points. A mathematically consistent description of these singular points becomes inevitable when we want to study the geometry of the separation. A separated stream surface requires, for example, the existence of a saddle-type singular point on the skin-friction surface. This singular point is actually, in the proper language of mathematics, a saddle of index two. The index is a measure of the dimension of the outset (set leaving the singular point). Hence, when a saddle of index two is specified, a two dimensional surface that becomes separated from the osculating plane of the saddle is implied. The three-dimensional singular point is interpreted mathematically and the most common aerodynamical singular points are discussed through this perspective. Author

N89-20965# Air Force Armament Lab., Eglin AFB, FL. Aerodynamics Branch.
A STUDY OF TRANSONIC DRAG REDUCTION OF A BLUNT CYLINDER BY A CYLINDER PROBE Final Report, 18 Oct. 1985 - 1 Jul. 1988 M.S. Thesis - Mississippi State Univ., MS - Aug.1987
DAVID H. BRIDGES Aug. 1988 69 p
(AD-A202557; AFATL-TR-88-95) Avail: NTIS HC A04/MF A01 CSCL 20D

This thesis examines the reduction of the drag of a blunt cylinder by a cylindrical probe in the transonic regime, and determines characteristics of the flowfield from the experimental drag coefficient data. The experiment was conducted in the NASA-Ames Research Center 6 x 6 ft supersonic wind tunnel. The model consisted of a blunt cylinder with diameter d2 and several extendable cylindrical probes, yielding probe-to-cylinder diameter ratios d1/d2 of 0.248, 0.368, an 0.45, an probe length-to-cylinder diameter ratios 1/d2 up to 2.0 (3.0 for the smallest probe). These configurations were tested at Mach numbers between 0.8 and 1.5. C sub D decreased as both 1/d2 and d1/d2 increased, due to the fact that the cylinder face was immersed in a wake of reduced stagnation pressure created by the probe. After reaching a minimum, C sub D increased as 1/d2 increased, indicating a transition of the flow over the probe from a lower-drag open cavity mode to a higher-drag open cavity mode to a higher-drag closed cavity mode. This change was rather abrupt, and there was also hysteresis in the supersonic tests in agreement with previous experiments. C sub D also reached a minimum and increased as d1/d2 approached 1. C sub D usually increased with Mach number due to the increase in stagnation pressure with M. For a particular range of length and diameter ratios, C sub D decreased with increasing M for 0.8 is less than M is less than 0.95. This was attributed to the transition of the flow over the probe from the high-drag closed mode to the low-drag open mode as M increased. GRA

N89-20966# Calspan Field Services, Inc., Arnold AFS, TN.
INVESTIGATION OF THE DEVELOPMENT OF LAMINAR BOUNDARY-LAYER INSTABILITIES ALONG A COOLED-WALL CONE IN HYPERSONIC FLOWS Final Report, 20 - 24 Jun. 1988
J. C. DONALDSON and M. G. HATCHER Dec. 1988 51 p Prepared in cooperation with Arnold Engineering D evelopment Center, Arnold AFS, TN
(AD-A202587; AEDC-TSR-88-V32) Avail: NTIS HC A04/MF A01 CSCL 01A

Measurements of fluctuating flow and mean flow parameters were made in the boundary layer on a cooled wall, sharp 7-deg (half-angle) cone in an investigation of wall temperature effects on the stability of laminar boundary layers in hypersonic flow. The flow fluctuation measurements were made using constant-current hot-wire anemometry techniques. Boundary-layer profiles and cone surface conditions were measured to supplement the hot-wire data. Testing was done at Mach numbers 8 and 6 with a free-stream unit Reynolds number of 1.0-million per foot. The test equipment, test techniques, and the data acquisition and reduction procedures are described. Analysis of the hot wire anemometer data is beyond the scope of this report. GRA

N89-20967# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
EFFECT OF RIBLETS UPON FLOW SEPARATION IN A SUBSONIC DIFFUSER M.S. Thesis
NATHAN W. MARTENS Dec. 1988 102 p
(AD-A203178; AFIT/GAE/AA/88D-23) Avail: NTIS HC A06/MF A01 CSCL 20D

This thesis investigates the effect of riblets upon flow separation in a two-dimensional straight-walled subsonic diffuser. Riblets are small flow-aligned grooves which can be attached to an aerodynamic body. Studies involving the application of riblets to turbulent flow over a flat plate have consistently shown a decrease in viscous drag as compared to the same surface without riblets. The purpose of this investigation was to determine the effect applying riblets to the walls of a subsonic diffuser would have upon flow separation in the fluid handling device. For this investigation, it was found separation was indeed delayed in a diffuser employing riblets as compared to a geometrically identical plain diffuser. For the smaller throat widths, this delay was significant, being as high as 250 percent due to riblets. As the diffuser throat width increased, the delay in flow separation due to riblets decreased. Also evident in the investigation was the strong dependence of flow separation upon throat velocity for the diffuser with riblets. GRA

N89-20968# National Aeronautical Establishment, Ottawa (Ontario).
AN EXPERIMENTAL STUDY OF TRANSONIC BUFFET OF A SUPERCRITICAL AIRFOIL WITH TRAILING EDGE FLAP
B. H. LEE and F. C. TANG Sep. 1988 85 p
(AD-A203189; NAE-AN-54) Avail: NTIS HC A05/MF A01 CSCL 01A

A supercritical airfoil with a trailing edge flap has been the subject of aerodynamic investigation in the National Aeronautical Establishment's High Reynolds Number 2-D Test Facility. The effects of flap deflection on buffet intensities and delay of buffet onset at transonic speeds were studied. Buffet boundaries for various flap angles were determined from the divergence of the fluctuating balance normal force measurements (C prime sub N). The onset of buffet was obtained from plots of C prime sub N versus C sub L at values of C sub L where the slope was 0.1. This value for the slope was arbitrarily chosen, but was found to give consistent results which agreed well with values computed from the criterion using the trailing edge pressure divergence for those cases where buffet onset is primarily due to trailing edge separation. For given flow conditions the deflection of the trailing edge flap altered the circulation and hence the position of the shock wave and its strength. The variations of these two quantities with flap angles were determined from pressure measurements carried out on the airfoil surface. The test was performed quite deep inside the buffet regime and shock wave oscillations were investigated from spectral analyses of the balance outputs. Fluctuations in the shock motion of approximately 70 Hz were detected. The drag of the airfoil was computed from the wake stagnation pressure deficit and the drag penalties for large flap angles were quite significant. GRA

N89-20969# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
NUMERICAL SIMULATION OF FLOW OVER ICED AIRFOILS M.S. Thesis
LARRY A. COLEMAN Dec. 1988 145 p
(AD-A203291; AFIT/GAE/AA/88D-4) Avail: NTIS HC A07/MF A01 CSCL 01A

This thesis evaluates the performance of an iced NACA 0012 airfoil numerically. The full Navier-Stokes equations are solved using the Beam-Warming algorithm. Steady-state solutions are obtained at a Mach number of 0.12 and a Reynolds number based

on chord of 1.41 million, for angles of attack from 2 to 8 deg. Lift and drag curves obtained from the numerical solutions were compared to experimental data and other numerical results. This comparison showed that the Beam-Warming algorithm provides a good estimate of the lift and drag at angles of attack below stall. Computed lift coefficients were within 11.5 percent of experimental data. These results were in excellent agreement with other numerical solutions. After stall, however, the code did not predict the expected decrease in lift and the calculated drag coefficient was much lower than the experimental data. Comparison of two local flowfield characteristics with the experimental data was less encouraging. A computed velocity profile was compared to the experimental profile for a station in the separated region on the upper surface. This comparison showed that the computed separation bubble is approximately one half the thickness of the bubble measured experimentally. Flow reattachment location is another measure of the predictive accuracy of the numerical scheme. GRA

N89-20970# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

THIN-LAYER NAVIER-STOKES SOLUTIONS FOR A CRANKED DELTA WING M.S. Thesis

FRANCIS R. SMITH Dec. 1988 100 p
(AD-A203292; AFIT/GAE/AA/88D-34) Avail: NTIS HC A05/MF A01 CSCL 20D

For thin, highly swept wings operating at moderate to high angles of attack, flow over the wing is dominated by formation of leading edge vortices. These vortices produce a minimum pressure which results in an additional lift increment. The lift increment is nonlinear with angle of attack and cannot be accurately predicted using present design methods. Thin-layer Navier-Stokes equations were used to calculate flow over a straight delta wing and a cranked delta wing. The straight delta wing was used as the test case due to the availability of both experimental and numerical procedure. The computer code uses an implicit, time marching algorithm developed by Beam and Warming. The solution is marched in time until a steady state is achieved. The code is approximately factored and diagonalized in order to reduce computational work. A solid state disk is used to allow for the large grid needed for a 3-D solution. Thin-layer Navier-Stokes equations are capable of accurately calculating vortical flows. The cranked delta wing exhibited flow similar to a straight delta wing upstream of the crank. The vortex generated at the crank quickly became paired with the vortex from the front of the wing. Vortex location aft of the crank changes with streamwise location. GRA

N89-20971# Air Force Inst. of Tech., Wright-Patterson AFB, OH. Aerodynamics and Airframe Branch.

TWO-DIMENSIONAL NAVIER-STOKES SOLUTION OF THE FLOW OVER A THICK SUPERCRITICAL AIRFOIL WITH STRONG SHOCK-INDUCED SEPARATION Interim Report, Jan. 1987 - Jan. 1988

DON W. KINSEY Nov. 1988 73 p
(AD-A203331; AFWAL-TR-88-3085) Avail: NTIS HC A04/MF A01 CSCL 20D

This report describes a numerical solution of the Navier-Stokes equations for transonic flow over a thick supercritical airfoil with strong shock-induced separation on both the upper and lower surfaces. The separated flow region extends from the shock (approximately 50 percent chord) to the trailing edge on both surfaces. The report first reviews the processes involved in producing a computational solution of the Navier-Stokes equations for a two-dimensional airfoil in a perfect gas. A brief development of the Navier-Stokes equations is provided. The solution algorithm used (an explicit predictor-corrector method) is developed and described. An algebraic turbulence model used to model the turbulent Reynolds stresses is described and the need for such a model is discussed. A hyperbolic, two-dimensional procedure for producing a computational grid (mesh) is also described. The boundary conditions imposed at the outer regions of the computational domain (farfield) and at the airfoil surface are discussed and described. The second part of the report discusses the treatment of the eddy viscosity development through the shock, in the separated regions over the airfoil and in the near wake. This work was critical for obtaining a successful solution on the very difficult test case chosen. GRA

N89-20972# George Washington Univ., Washington, DC.

METHODOLOGY FOR USING STEADY EXPERIMENTAL AERODYNAMIC DATA TO IMPROVE STEADY AND UNSTEADY AERODYNAMIC ANALYSIS M.S. Thesis

CAROL DANIELLE WIESEMAN Feb. 1989 110 p
Avail: NTIS HC A06/MF A01

Correction factor methodologies were developed which use steady experimental or accurate analytical pressure or force data to correct steady and unsteady aerodynamic calculations obtained by simpler methods. Three methods of calculating these factors were developed to match steady lifting pressure distributions, airfoil section properties (lift and moment derivatives) and total force and moment derivaties with respect to angle of attack and control surface deflection. A rectangular supercritical wing previously tested in the NASA-Langley Transonic Dynamics Tunnel was used as a test case for the methodology. The reasons for choosing this wing as a test case were that an abundance of pressure data were available, both steady and unsteady, at Mach numbers ranging from subsonic and transonic, for a range of reduced frequencies. This test case was a severe test for the methodology. Correction factors were calculated to match distributions of lifting pressure derivatives or to match section lift and moment derivatives obtained by the doublet lattice method to the corresponding steady state experimental values. These factors were then applied to steady and unsteady aerodynamic calculations. Author

N89-20973*# Continuum Dynamics, Inc., Princeton, NJ.

PERFORMANCE OPTIMIZATION FOR ROTORS IN HOVER AND AXIAL FLIGHT

T. R. QUACKENBUSH, D. A. WACHSPRESS, A. E. KAUFMAN, and D. B. BLISS (Duke Univ., Durham, NC.) Apr. 1989 41 p
(Contract NAS2-12789)
(NASA-CR-177524; NAS 1.26:177524) Avail: NTIS HC A03/MF A01 CSCL 01A

Performance optimization for rotors in hover and axial flight is a topic of continuing importance to rotorcraft designers. The aim of this Phase 1 effort has been to demonstrate that a linear optimization algorithm could be coupled to an existing influence coefficient hover performance code. This code, dubbed EHPIC (Evaluation of Hover Performance using Influence Coefficients), uses a quasi-linear wake relaxation to solve for the rotor performance. The coupling was accomplished by expanding of the matrix of linearized influence coefficients in EHPIC to accommodate design variables and deriving new coefficients for linearized equations governing perturbations in power and thrust. These coefficients formed the input to a linear optimization analysis, which used the flow tangency conditions on the blade and in the wake to impose equality constraints on the expanded system of equations; user-specified inequality contraints were also employed to bound the changes in the design. It was found that this locally linearized analysis could be invoked to predict a design change that would produce a reduction in the power required by the rotor at constant thrust. Thus, an efficient search for improved versions of the baseline design can be carried out while retaining the accuracy inherent in a free wake/lifting surface performance analysis. Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A89-33825
PREDICTING THE EFFECTS OF AIRCRAFT ICING
Aerospace Engineering (ISSN 0736-2536), vol. 9, March 1989, p. 23-26.

The type and quantity of ice that accumulates on an aircraft external component's leading edge depends on the physical properties of the icing cloud, the geometry of the aircraft component, local aerodynamic conditions, and the duration of the water droplet/surface encounter. Aircraft components with relatively high radii of curvature have been found to deflect a greater portion of the smaller droplets, thereby avoiding severe icing; the greatest danger accordingly lies with components having smaller radii of curvature, as found in many general aviation aircraft. Attention is given to the results of efforts to determine the effects of surface icing on flying qualities. O.C.

A89-34444* Miami Univ., Coral Gables, FL.
COCKPIT AUTOMATION
EARL L. WIENER (Miami, University, Coral Gables, FL) IN: Human factors in aviation. San Diego, CA, Academic Press, Inc., 1988, p. 433-461. refs
(Contract NCC2-377)

The aims and methods of aircraft cockpit automation are reviewed from a human-factors perspective. Consideration is given to the mixed pilot reception of increased automation, government concern with the safety and reliability of highly automated aircraft, the formal definition of automation, and the ground-proximity warning system and accidents involving controlled flight into terrain. The factors motivating automation include technology availability; safety; economy, reliability, and maintenance; workload reduction and two-pilot certification; more accurate maneuvering and navigation; display flexibility; economy of cockpit space; and military requirements. T.K.

A89-34885#
EXPERIMENTAL INVESTIGATION OF ELECTROSTATIC FIRE ACCIDENTS AFTER AIRCRAFT LANDING AND PREVENTIVE MEASURES
HANSHENG LUO (Air Force, Institute, Beijing, People's Republic of China) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 405-409.

This work is an experimental investigation to determine the cause of electrostatic fire accidents after aircraft landing and to clarify the effects of various factors on the cause. This research work has conducted a series of ground simulation tests and actual flight tests under the fire and explosion environment conditions. The test results have indicated that the process of an aircraft landing run is the fundamental process of electrostatic charges generating in fuel tanks. After an aircraft comes to a stop, there is also a process of accumulation of electrostatic charges, while fuel charged with higher energy remains for a considerably long period, unable to dissipate. All kinds of unbonded conductors in the tank are electrodes for dangerous spark discharges. When an aircraft using RP-2 fuel flies in hot weather, the concentration of flammable vapor produced in the space above the fuel surface inside of the tank will, under certain conditions, come close to its chemical equivalent, thus possessing the condition of combustibles under which an electrostatic spark can cause fires and explosions. Some principles that should be followed in aircraft fuel system design are discussed. Author

A89-34889#
DETERMINING AND ACCOUNTING FOR A PARACHUTE VIRTUAL MASS
T. YAVUZ (Karadeniz Technical University, Trabzon, Turkey) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 432-437. refs

The concept of virtual mass is described, and experiments are outlined in which virtual mass and virtual inertia components for a parachute canopy were determined. Results show that these components depend on the canopy shape and its attitude relative to the airflow; they also depend on the dimensionless acceleration, or acceleration number, of the parachute. Except at high values of acceleration number, these virtual inertia terms are of greater magnitude than corresponding values determined by potential flow methods, and this is characteristic of unsteady bluff-body flows. Their significance is indicated in dynamic behavior prediction for the descending fully deployed parachute canopy. Author

A89-34891#
MODELING OF PARACHUTE OPENING - AN EXPERIMENTAL INVESTIGATION
CALVIN K. LEE (U.S. Army, Research, Development, and Engineering Center, Natick, MA) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 444-451. refs

Scaling parameters for the peak opening force and opening time of solid cloth parachutes are investigated using the physical modeling technique. Using Froude number and mass ratio as the two scaling parameters, the correlation of the nondimensional peak opening force and opening time between the full-scale and the model parachutes made from the same 1.1 oz/sq yd ripstop nylon was not entirely satisfactory. Nylon fabrics with areal densities up to 14 oz/sq yd were then used to construct full-scale parachutes so that the 1.1 oz/sq yd model parachute would have a lighter fabric. This improved the correlation between the full-scale parachutes and the model parachute, and established the importance of scaling canopy fabric as well as Froude number and mass ratio for modeling parachute opening. Author

A89-35158*# National Severe Storms Lab., Norman, OK.
TRIGGERED LIGHTNING STRIKES TO AIRCRAFT AND NATURAL INTRACLOUD DISCHARGES
VLADISLAV MAZUR (NOAA, National Severe Storms Laboratory, Norman, OK) Journal of Geophysical Research (ISSN 0148-0227), vol. 94, March 20, 1989, p. 3311-3325. Research supported by NASA. refs

The physical model of Mazur (1989) for triggering lightning strikes by aircraft was used to interpret the initiation of intracloud flashes observed by the French UHF-VHF interferometric system. It is shown that both the intracloud discharges and airplane-triggered lightning strikes were initiated by simultaneous bidirectional development of the negative stepped leader and the positive leader-continous current process. However, the negative stepped leader phase in triggered flashes is of shorter duration (tens of milliseconds), than that in intracloud flashes (usually hundreds of milliseconds). This is considered to be due to the fact that, on the aircraft there is a single initiation process, versus the numerous initiation processes that occur inside the cloud. I.S.

A89-35200#
ADVANCED TECHNIQUES USED IN KANISHKA AIRCRAFT ACCIDENT INVESTIGATION
H. S. KHOLA (Directorate General of Civil Aviation, New Delhi, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 215-220.

This paper discusses methods used in the investigation of the June 23, 1985 accident involving an Air India aircraft, Kanishka, which left no survivals or witnesses and only 3-5 percent of aircraft wreckage, mostly nonstructural parts, floating on water, close to the position in the Atlantic Ocean where the aircraft disappeared from the radar screan. Data available included the cockpit voice recorder tapes; microscopic examinations of the forward cargo compartment skin and the fuselage skin around the 2R door; examination of bodies recovered; and comparisons of observations on the wreckage remains with fractures produced in experimental explosion in skin panels, stringers, and tubes. Data led to the

conclusion that the cause of the accident was a bomb explosion. Evidence is presented that connects the Kanishka explosion with a bomb explosion at the Narita airport. I.S.

A89-35201
AIAA AERODYNAMIC DECELERATOR SYSTEMS TECHNOLOGY CONFERENCE, 10TH, COCOA BEACH, FL, APR. 18-20, 1989, TECHNICAL PAPERS
Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 326 p. For individual items see A89-35202 to A89-35247.

The present conference on advanced aerodynamic decelerator technologies discusses prospective U.S. Army airdrop technology requirements, future aircraft escape capsules, high-altitude decelerator systems, pilot ejection from a prone flying position, an inflatable triangular accelerator, a novel recovery parachute system for the F-111 crew-escape module, the prediction of parachute collapse due to wake recontact, the tethered parafoil test technique, and a piloted cargo-delivery system employing ram-air parachutes. Also discussed are a 10,000-lb capacity ram-air parachute, the numerical analysis of three-dimensional nonrigid wings, innovative parachute materials, lightweight Kevlar parachute fabrics, aging effects on nylon parachutes, a low-altitude tactical assault parachute, a national data bank on parachute textile materials, a vortex-panel analysis of circular-arc bluff-bodies in unsteady flow, a seat-mounted combined harness, and a 'whirltower' test facility. O.C.

A89-35207#
AERIAL DELIVERY OF PERSONNEL IN GROUND PROXIMITY
HENRY J. HUNTER (Douglas Aircraft Co., Long Beach, CA) and MICHAEL J. WUEST (USAF, Flight Test Center, Edwards AFB, CA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 38-43.
(AIAA PAPER 89-0887)

The long-used low-altitude parachute extraction system (LAPES) by which heavy equipment and supplies can be offloaded from an aircraft flying just above ground level is presently extended to deliver military personnel capsules that will preclude the wide dispersion and great vulnerability of parachute drops. Attention is given to the limits of human tolerance to the decelerations associated with this type of LAPES application; the means of controlling or limiting these deceleration forces are analyzed, and the results from earlier tests using a ground proximity extraction system are compared with those for a LAPES. Basic design concepts for a LAPES personnel capsule are presented. O.C.

A89-35210#
A CONTROL CANOPY RELEASE METHOD FOR IMPROVED OPENING OF CLUSTERED PARACHUTES
CALVIN K. LEE and JAMES E. SADECK (U.S. Army, Research, Development and Engineering Center, Natick, MA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 53-59. refs
(AIAA PAPER 89-0892)

This paper presents a concept and a method for achieving simultaneous opening of clustered parachutes. The concept is to inflate the parachutes in a cluster as though they were one large parachute. The method involves partial reefing of the parachutes, connecting them together during opening, and releasing them at almost full inflation. This method, called control canopy release method, was tested with two-G12 (64-foot-diameter, flat-circular cargo parachutes), three-G12, and three-C9 (28-foot-diameter, flat-circular, personnel parachutes) clusters. Their opening was significantly improved when compared to the opening of the clusters without using this method. Author

A89-35211#
HIGH ALTITUDE PARACHUTE AND ITS MILITARY APPLICATIONS
M. L. CHAURASIA and RAJESH KUMAR (Aerial Delivery Research and Development Establishment, Agra, India) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 60-63. refs
(AIAA PAPER 89-0893)

The high altitude parachute (HAP) design presently discussed was first projected as a military requirement in light of the inadequacies and hazards associated with parachuting at high altitudes. The design proceeds from the environmental characteristics of low air density, atmospheric pressure variations, etc. A three-stage HAP deployment scheme addresses the hazards associated with emergence from a high-speed aircraft at extreme altitudes; a nylon fabric of ultralow porosity has been developed and incorporated into the design to preclude an initially excessively swift descent. O.C.

A89-35212#
THE DEVELOPMENT OF THE PANEL STABILIZED SLOTTED-SQUARE PARACHUTE
CARL T. CALIANNO (U.S. Navy, Naval Air Development Center, Warminster, PA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 64-70.
(AIAA PAPER 89-0894)

Stabilization panels have been incorporated by a slotted square parachute. Wind tunnel tests have been conducted to ascertain how various stabilizing panel configurations affect the drag and stability performance of this parachute configuration; the configurations extended to ribless-guide surface, conical, and cross parachutes. These parachutes have furnished reference-points for the determination of wind tunnel test technique accuracy and the comparison of novel design performance characteristics with those of existing parachute types. Flight testing was then conducted to verify wind tunnel results. It is found that simple stabilizing panels will yield twice the stabilizing moment as ribless parachute configurations. O.C.

A89-35213#
A REVISION OF THE ADDED MASS CONCEPT AS APPLIED TO PARACHUTE MOTION
D. J. COCKRELL, Y. I. FRUCHT, and R. J. HARWOOD (Leicester, University, England) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 71-77. Research supported by the Ministry of Defence Procurement Executive. refs
(AIAA PAPER 89-0895)

A parachute canopy is an immersed body for which the rate of change of momentum of the air in which it is immersed is of the order of that of the canopy and hence the equations of motion for the latter must also include the former. This rate of change of momentum of the air is allowed for by added mass components, the magnitudes of which must be determined experimentally. In general, unsteady motion through fluids of bluff bodies like parachute canopies is very complex and the coefficients of these added mass components can be shown to be dependent on the immersed body shape and attitude, the flow Reynolds number and on either the instantaneous acceleration number or the oscillation's Keulegan-Carpenter number. However, at the Keulegan-Carpenter numbers normally encountered by the oscillatory pitching motion of fully-inflated parachute canopies the relevant added mass coefficient are of negligible magnitudes and need not be considered further in the relevant equations of motion. The effects of neglecting these added mass coefficients are considered by reference to the root-locus diagram which follows from their linearization. Author

A89-35219#
TETHERED PARAFOIL TEST TECHNIQUE
GLEN J. BROWN (Vertigo, Inc., Lake Elsinore, CA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 110-113. Research supported by the Developmental Sciences Corp.
(AIAA PAPER 89-0903)

A test technique has been developed and is now in use that is effective in measuring the performance of full scale Parafoils. The method involves tethering the Parafoil under test to an instrumented test rig on a truck. Measurements of airspeed, tether tension and tether angle are used to determine the Parafoil's L/D and lift coefficient. For development testing a device is added that allows trim and camber changes to be made while running. The test rig has been used with Parafoils from 18 sq ft to 800 sq ft. Data reduction techniques and examples of results are presented. Author

A89-35220#
THE DEVELOPMENT OF A 10,000 LB CAPACITY RAM AIR PARACHUTE
E. PUSKAS (Para-Flite, Inc., Pennsauken, NJ) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 114-120. Research supported by Para-Flite, Inc.
(AIAA PAPER 89-0904)

The design and development of a 3,000 sq ft, 10,000 lb capacity, ram air parachute is described. Design philosophy structural and aerodynamic considerations of the design, manufacturing and testing are outlined and discussed. Because large ram air parachutes carrying thousands of pounds become unguided missiles during testing, it was necessary to develop a means of controlling and guiding the parachute during the test phase. The means of guidance developed for this purpose is also covered, although briefly. Author

A89-35221#
EVOLUTION OF THE MANTA-RAY PARACHUTE
M. J. RAVNITZKY (Irvin Industries, Inc., Santa Ana, CA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 121-124. refs
(AIAA PAPER 89-0906)

The 'manta-ray' parachute configuration, which can be characterized as a ring-sail parachute with ram air-inflated leading edge, has demonstrated L/D values as high as 2.17 in extensive ground and aerial testing. Technical concerns to which attention was given during developmental testing encompassed reefing, leading-edge collapse, L/D modulation, and turn control. A comparison of test results with ram-air parachute performance suggests a continuum between the characteristics of inflated airfoil parachutes and those of ballistic parachutes incorporating a glide capability. The data obtained on various parachute parameters may be applicable to ram-air parachute optimization. O.C.

A89-35223#
DEVELOPMENT OF AN ALTERNATING FLAT TO TUBULAR KEVLAR PARACHUTE TAPE
R. H. ERICKSEN (Sandia National Laboratories, Albuquerque, NM) and R. KOCH (Bally Ribbon Mills, PA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 133-142. Research supported by USAF.
(AIAA PAPER 89-0910)

An alternating flat to tubular Kevlar tape was developed to replace braided suspension lines and woven tape radials on the new crew escape module parachute system for the F-111 aircraft. Weaves were developed which had high strength efficiency and low weight throughout the flat, tubular, and transition sections. A tubular section strength of 535 lbs at a weight of 0.044 oz/yd was achieved. This reduces suspension line weight by 8 percent compared with that of the most efficient braid which has a strength of 470 lbs and weighs 0.048 oz/yd. Length measuring procedures for production control and inspection were developed. Using these procedures it was possible to produce alternating weave fabric with less than 1 percent variation in length in the tubular sections. Author

A89-35227#
INVESTIGATION OF THE SERVICE AND AGE LIVES OF U.S. ARMY PERSONNEL PARACHUTES
ROBERT J. COSKREN (Albany International Research Co., Mansfield, MA) and ERWIN A. WUESTER (U.S. Army, Research, Development and Engineering Center, Natick, MA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 159-165. refs
(AIAA PAPER 89-0915)

The suspension lines from 30 U.S. Army and 32 U.S. Forestry Service parachutes were studied to determine the effect of age and/or service on their tensile behavior. The data showed a gradual loss of line strength with age and/or service of the U.S. Forestry Service parachutes studied. The controlled deployment of four parachutes at the Yuma Proving Ground and the Naval Weapons Center indicated that the deployment of a parachute under severe conditions of load or velocity can result in seriously weakened suspension lines. This may be due to the development of structural imbalance between the core and sheath of the line. K.K.

A89-35228#
PERSONNEL PARACHUTE AGE/SERVICE LIFE CRITERIA
ROBERT W. RODIER, ERWIN A. WUESTER, and JAMES E. HALL (U.S. Army, Research, Development and Engineering Center, Natick, MA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 166-171. refs
(AIAA PAPER 89-0916)

A simple dynamic test technique is developed for laboratory testing of Army personnel parachute suspension lines in order to provide insight into their degradation mechanisms. Cyclic loading tests of MIL-C-5040 Type II nylon cord are performed using a 10 minute relaxation period between loadings on clean lines and lines contaminated with sand and grit particles. It is found that the primary source of suspension line strength degradation is the incidental inclusion of sand and grit particles during parachute retrieval. Most strength loss occurs during the first 30-50 cycles or uses. The number of uses and geographical differences in sand particles are found to be far more important in establishing the service life than is date of manufacture. S.A.V.

A89-35231#
THE DEVELOPMENT AND TESTING OF THE HISAC PARACHUTE RECOVERY SYSTEM
VANCE L. BEHR (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 187-192. Research sponsored by the U.S. Army. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0921)

Through the use of analyses and airdrop and ground tests, a high performance parachute recovery system has been developed for the High Speed Airdrop Container (HISAC) program. Airdrop and ground test results indicate that the use of a reefed and staged drogue in conjunction with a cluster of three standard unreefed T-10 personnel parachutes provides the best combined turnover and impact velocity characteristics. Initial deployment of the drogue parachute is produced by an aerodynamically deployed

tailplate which produces no appreciable carriage drag. Ground test results indicate that reliable deployment of the tailplate is achieved through the use of aerodynamic drag surfaces which are deployed shortly after the HISAC is released from the carriage aircraft. S.A.V.

A89-35233#
MEASUREMENTS OF INDIVIDUAL PARACHUTE LOADS IN A CLUSTERED PARACHUTE SYSTEM
VANCE L. BEHR (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 202-205. Research supported by USAF.
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0923)

A small rugged load sensor which can be installed in the riser of a parachute system to directly measure parachute loads has been developed. The load sensor consists of a clevis, a spool, and an instrumented clevis pin. Multiple sensors can be installed in each riser of a clustered parachute system to measure the loads developed by each parachute. The results are presented from preliminary tests of the load sensor. R.B.

A89-35234#
SMALL PARACHUTE FLIGHT DATA ACQUISITION SYSTEM
D. E. RYERSON and G. C. HAUSER (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 206-210.
(AIAA PAPER 89-0924)

A small data acquisition system for parachute design and testing is examined. The system consists of a microprocessor-controlled unit which digitizes data from up to eight analog gauge inputs and stores the digitized data. The system specifications are listed and mechanical, electrical, and software descriptions of the system are given. The use of the system in parachute and water entry tests is discussed. R.B.

A89-35245#
A SEAT-MOUNTED COMBINED HARNESS
J. P. MURRAY (Grumman Corp., Aircraft Systems Div., Bethpage, NY) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 297-301.
(Contract N62269-83-C-0233)
(AIAA PAPER 89-0937)

The preliminary development of a seat-mounted combined harness and survival undergarment for the U.S. Navy that meets the criteria of flight restraint, ejection, parachuting, and crash conditions is discussed. This effort was part of an attempt to develop and qualify a number of specific point designs for retrofitting improved restraint equipment into various operational escape systems. Harnesses were manufactured to conduct ejection tower testing, windblast tests, water drag tests, negative 'g' tests, cockpit compatibility tests, and live parachute jumps over land and water. K.K.

A89-35841
TRANSONIC/SUPERSONIC (720 KEAS 1.2 MACH) EJECTION DEMONSTRATION TEST OF AN S4S BIOFIDELITY MANIKIN (BFM1)
LAWRENCE E. KINKER, ROBERT MCCONNELL, GEORGE FRISCH (U.S. Navy, Naval Air Development Center, Warminster, PA), and DONALD E. MCCAULEY (Universal Propulsion Co., Inc., Phoenix, AZ) SAFE Journal, vol. 19, Spring 1989, p. 8-13.

In September 1988 a 725 KEAS ejection demonstration test was conducted at Hurricane Mesa, Utah, using an S4S ejection seat and Navy configured Biofidelic Manikin. The conduct of this test was specifically geared toward demonstrating the feasibilty of aircrew recovery at transonic/supersonic air speed with a conventional open-type ejection seat (S4S) and highlighting the effectiveness and relevance of ongoing Navy 6.2 and 6.3 programs as they relate to the conduct and evaluation of test programs demonstrating improved life support equipment. This demonstration verified the operation of the IH-1 restraint harness, a U.S. Navy developed instrumentation system incorporated into a modified Biofidelic Manikin (which closely emulates the elasticity and rigidity of the human spine), and stabilization fins which had previously been developed for the S4S ejection seat. Author

A89-35845
A PRONATED ESCAPE SYSTEM FOR FIGHTER AIRCRAFT
JEFF OLINGER, JEFF NICHOLSON (USAF, Kirtland AFB, NM), and STUART KRAMER (USAF, Institute of Technology, Wright-Patterson AFB, OH) SAFE Journal, vol. 19, Spring 1989, p. 50-55. refs

A forward-leaning (pronated) seat design is proposed which meets the requirements of providing adequate support for the pilot during high-acceleration maneuvers, as well as the means of escaping the aircraft in an emergency over a wide range of speeds, altitudes, and attitudes. The predicted performance of the pronated escape system (PRESS) was estimated for three injury risk levels. It was shown that the PRESS seat with a seat front angle of 35 deg offers increased g-tolerance over conventional upright seats and the same g-tolerance as a 65-deg reclined seat. Compared with existing ejection capsules, the seat is very light, and yet offers better protection than capsules. I.S.

A89-36019#
PARACHUTES - YESTERDAY, TODAY, AND TOMORROW
T. W. KNACKE AIAA, Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989. 8 p. refs
(AIAA PAPER 89-0880)

A brief historical overview of parachute development is presented, citing their use from 1930 to the use of drogue chutes for Space Shuttle SRB recovery. Figures presented show the growth of parachute deployment velocity from the 1940s to the 1990s and the growth in parachute fabric fiber strength from 1930 to 1980. Future requirements for parachutes in the field of air vehicle recovery are cited, including high-strength materials, high-drag parachute canopies, and low total parachute forces, in order for parachute assemblies to have minimum weight and compartment volume. The need for a new whirl tower with performance matching current requirements is mentioned. S.A.V.

A89-36020#
RADIUS-TIPPED TRIANGULAR INFLATABLE DECELERATOR DESIGN AS AFFECTED BY PRODUCEABILITY/SURVIVABILITY CONSTRAINTS
PATRICK J. CANNON and MARK A. KOCH (Raven Industries, Inc., Sioux Falls, SD) AIAA, Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989. 9 p.
(AIAA PAPER 89-0888)

A concept for a sewn fabric decelerator/stabilizer is presented and discussed. General requirements for the device are presented and strengths and limitations of various competing concepts are contrasted and discussed. The conflict between the need for simple, low cost design for high volume produceability and more complex designs and usage of expensive materials in order to ensure survivability is discussed. A proprietary Raven Industries design is presented which addresses this conflict by using flat-panel construction to create a decelerator which develops an effective three dimensional shape when inflated. Conceptual sketches of decelerator designs are provided. Author

N89-20108# National Transportation Safety Board, Washington, DC. Bureau of Safety Programs.
AIRCRAFT ACCIDENT DATA, US GENERAL AVIATION, CALENDAR YEAR 1986 Annual Review Report
25 Oct. 1988 166 p

(PB89-121453; NTSB/ARG-88/01) Avail: NTIS HC A08/MF A01 CSCL 01C

The report presents a statistical compilation and review of general aviation accidents which occurred in 1986 in the United States, its territories and possessions, and in international waters. The accidents reported are all those involving U.S. registered aircraft not conducting operations under 14 CFR 121, 14 CFR 125, 14 CFR 127, or 14 CFR 135. The report is divided into five sections: All Accidents; Fatal Accidents; Serious Injury Accidents; Property Damage Accidents and Midair Collision Accidents. Several tables present accident parameters for 1986 accidents only, and each section includes tabulations which present comparative statistics for 1986 and for the five-year period 1981 to 1985. GRA

N89-20109# National Transportation Safety Board, Washington, DC. Bureau of Field Operations.
AIRCRAFT ACCIDENT REPORTS: BRIEF FORMAT, US CIVIL AND FOREIGN AVIATION, ISSUE NUMBER 12 OF 1986 ACCIDENTS
30 Mar. 1988 427 p
(PB88-916902; NTSB/AAB-88/02) Avail: NTIS HC A19/MF A01; also available on subscription, North American Continent HC $185.00/year; all others write for quote CSCL 01C

The publication contains selected aircraft accident reports in Brief Format occurring in U.S. civil and foreign aviation operations during Calendar Year 1986. Approximately 200 General Aviation and Air Carrier accidents contained in the publication represent a random selection. The publication is issued irregularly, normally eighteen times each year. The Brief Format represents the facts, conditions, circumstances, and probable cause(s) for each accident. GRA

N89-20110# National Transportation Safety Board, Washington, DC. Bureau of Field Operations.
AIRCRAFT ACCIDENT REPORTS, BRIEF FORMAT, US CIVIL AND FOREIGN AVIATION, ISSUE NUMBER 14 OF 1986 ACCIDENTS
11 Aug. 1988 347 p
(PB88-916904; NTSB/AAB-88/04) Avail: NTIS HC A15/MF A01; also available on subscription, North American Continent HC $185.00/year; all others write for quote CSCL 01C

The publication contains selected aircraft accident reports in Brief Format occurring in U.S. civil and foreign aviation operations during Calendar Year 1986. Approximately 200 General Aviation and Air Carrier accidents contained in the publication represent a random selection. The publication is issued irregularly, normally eighteen times each year. The Brief Format represents the facts, conditions, circumstances and probable cause(s) for each accident. GRA

N89-20111*# Sierra Nevada Corp., Reno.
ANALYSIS OF DOPPLER RADAR WINDSHEAR DATA Final Report
F. WILLIAMS, P. MCKINNEY, and F. OZMEN Jan. 1989 189 p
(Contract NAS1-18598)
(NASA-CR-181762; NAS 1.26:181762; DOT/FAA/PS-88/19)
Avail: NTIS HC A09/MF A01 CSCL 01C

The objective of this analysis is to process Lincoln Laboratory Doppler radar data obtained during FLOWS testing at Huntsville, Alabama, in the summer of 1986, to characterize windshear events. The processing includes plotting velocity and F-factor profiles, histogram analysis to summarize statistics, and correlation analysis to demonstrate any correlation between different data fields. Author

N89-20112# National Transportation Safety Board, Washington, DC. Bureau of Accident Investigation.
AIRCRAFT ACCIDENT REPORT: CONTINENTAL AIRLINES, INC., FLIGHT 1713, MCDONNELL DOUGLAS DC-9-14, N626TX, STAPLETON INTERNATIONAL AIRPORT, DENVER, COLORADO, NOVEMBER 15, 1987
27 Sep. 1988 97 p
(PB88-910411; NTSB/AAR-88/09) Avail: NTIS HC A05/MF A01; also available on subscription, North American Continent HC $70.00/year; all others write for quote CSCL 01C

The National Transportation Safety Board decided that the probable cause of the accident was the captain's failure to have the aircraft deiced a second time after a delay before takeoff that led to upper wing surface contamination and a loss of control during rapid takeoff rotation by the first officer. Contributing to the accident were the absence of regulatory or management controls governing operations by newly qualified flight crew members and the confusion that existed between the flight crew and the air traffic controllers that led to the delay in departure. Author

N89-20974# General Accounting Office, Washington, DC.
AVIATION SAFETY: MEASURING HOW SAFELY INDIVIDUAL AIRLINES OPERATE
Mar. 1988 40 p
(GAO/RCED-88-61) Avail: NTIS HC A03/MF A01

The deregulation of airline fares and schedules in 1978 led to rapid growth and change in the airline industry, placing increased burdens on FAA'S airline inspection program. Because of growing concern that airlines may be operating less safely under deregulation, improved ways to measure how safely individual airlines operate are sought. Information was provided on the feasibility of developing and publishing for air travelers indicators that compare how safely individual airlines operate. The focus was on identifying: areas of airline performance recognized as important to airline safety, the availability and quality of data in these areas, and ongoing research on measuring individual airline safety. Author

N89-20975# Naval Environmental Prediction Research Facility, Monterey, CA.
ICING CONSIDERATIONS FOR HALE (HIGH ALTITUDE, LONG ENDURANCE) AIRCRAFT Final Technical Report
GERARD N. VOGEL Nov. 1988 54 p
(AD-A202584; NEPRF-TR-88-11) Avail: NTIS HC A04/MF A01 CSCL 04B

Although a low probability event, ice accretion does present a major obstacle to safe aircraft operations. In this report, the character of the aircraft icing environment is explored in terms of key meteorological and aerodynamic factors as related to the HALE (High Altitude, Long Endurance) aircraft. The distribution of icing in the atmosphere, mainly a function of temperature and cloud structure, is presented. Ice forecasting techniques and icing instrumentation are discussed as viable approaches for minimizing potential aircraft icing hazards. It is concluded that an onboard ice accumulation detector in combination with ground-based remote sensing instrumentation would provide the best capability icing forecasting program, which is often both effort- and time-efficient, is recommended. GRA

N89-20976# Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH.
IN-FLIGHT LIGHTNING CHARACTERIZATION PROGRAM ON A CV-580 AIRCRAFT Final Report, Oct. 1983 - Sep. 1987
HAROLD D. BURKET, LAWRENCE C. WALKO, JEAN S. REAZER, and ARTURO V. SERRANO Jun. 1988 185 p
(AD-A203954; AFWAL-TR-88-3024) Avail: NTIS HC A09/MF A01 CSCL 04B

A CV-580 aircraft was instrumented with external displacement current density sensors, surface current density sensors, current shunts, and static electric field mill sensors and was flown in active thunderstorms in central Florida during the summer of 1984 and 1985. Electromagnetic data were collected and analyzed for 52 direct lightning strikes to the aircraft flying at altitudes between 2,000 and 18,000 ft. The data consisted of analog records with dc to 2-MHz bandwidth and 10-us windows of digital samples taken at 5-ns intervals. The data show the physical mechanism of lightning attachment to aircraft and suggest comparison of aircraft responses to lightning and simulated NEMP is also provided. GRA

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

A89-33567
DATA LINKS FOR VIDEO AND IR SURVEILLANCE
JOHN R. SHARMAN (STC Defence Systems, PLC, Radio and Microwave Div., Paignton, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 21.1-21.12. Research supported by the Ministry of Defence.

Four data link types for robotic surveillance aircraft applications are presented whose architectures are modular and reconfigurable to meet a wide variety of requirements with minimum time and cost. QPSK and TDM are employed in the RF communications system design to permit tuning over a wide band, and both low-GHz and multi-GHz RF architectures can be implemented using a common modem and channelization architecture. Spread-spectrum coding may be added to the downlink in order to protect the telemetry and sensor timing. The high level of antijamming performance thus achieved furnishes further gains in flexibility. O.C.

A89-33572
DEVELOPMENT OF A LOW COST TRACKING/RANGING SYSTEM
H. CUCKSON IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 20.1-20.5.

An account is given of the Skytrack low cost tracker for unmanned aircraft (UMA) operations, which in addition to location-finding furnishes all the up/downlinks required by surveillance and target-practice UMAs. A phase-comparison interferometer system was chosen for the tracker, since it can furnish high accuracy and resolution with antennas that are of only modest gain. The transmitter is of conventional, D-band telemetry type, with a stabilized oscillator. The system is highly portable, and can be set up by a single person. The development capability for a covert, ECM-resistant system is also offered. O.C.

A89-33573
SOME CONSEQUENCES OF REDUCED FRAME RATE FOR OPERATOR PERFORMANCE
MICHAEL H. REJMAN (Army Personnel Research Establishment, Farnborough, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 22.1-22.7. refs

Results are presented from an experiment which examined the effect of reduced frame-rate TV transmission from RPVs, in order to reduce bandwidth requirements while retaining the real-time surveillance capabilities required in terrain feature-following flying tasks. Attention was also given in this study to the effects of such image manipulation on the secondary task of target-detection. The results obtained demonstrate that frame-rate reduction can have serious deleterious effects on the conduct of such tasks. The implications of these results for the operation of RPVs are discussed, with emphasis on the importance of human factors considerations. O.C.

N89-20113*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
HIGH-DYNAMIC GPS TRACKING Final Report
S. HINEDI and J. I. STATMAN 15 Dec. 1988 95 p
(Contract NAS7-918)
(NASA-CR-184868; JPL-PUBL-88-35; NAS 1.26:184868) Avail: NTIS HC A05/MF A01 CSCL 17G

The results of comparing four different frequency estimation schemes in the presence of high dynamics and low carrier-to-noise ratios are given. The comparison is based on measured data from a hardware demonstration. The tested algorithms include a digital phase-locked loop, a cross-product automatic frequency tracking loop, and extended Kalman filter, and finally, a fast Fourier transformation-aided cross-product frequency tracking loop. The tracking algorithms are compared on their frequency error performance and their ability to maintain lock during severe maneuvers at various carrier-to-noise ratios. The measured results are shown to agree with simulation results carried out and reported previously. Author

N89-20114# Royal Signals and Radar Establishment, Malvern (England).
THE APPLICATION OF SOFTWARE FAULT TOLERANCE TO AIR TRAFFIC CONTROL: STUDY CONTRACT OVERVIEW
L. N. SIMCOX Jun. 1988 21 p
(BR108567; RSRE-MEMO-4114) Avail: NTIS HC A03/MF A01

An overview of research done on the application of software fault tolerance to air traffic control (ATC) systems is provided. A requirements analysis of the London Air Traffic Control Centre (LATCC) was developed using the CORE method with automated support. This was then taken as the basis for a MASCOT design of the LATCC Radar Data Processing subsystem. This design was converted into one with the software fault tolerant features of Recovery Blocks in a MASCOT-like environment. Author

N89-20115# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
THE APPLICATION OF TRAJECTORY PREDICTION ALGORITHMS FOR PLANNING PURPOSES IN THE NETHERLANDS AIR TRAFFIC CONTROL (ATC) SYSTEM
J. N. P. BEERS, T. B. DALM, J. M. TENHAVE, and H. VISSCHER
29 Oct. 1986 15 p Submitted for publication
(NLR-MP-87031-U; ETN-89-94034) Avail: NTIS HC A03/MF A01

The Netherlands ATC-environment, the basic set-up of the trajectory prediction module, improvements realized, and the performance figures are presented. Applications of the trajectory prediction results in the system are listed, including data distribution rules, presentation of estimated times of arrival, boundary estimates, and, in particular, long-term detection of conflicts for overflying aircraft, planning in inbound traffic for Schiphol airport, and planning of departure times for an efficient engine start-up procedure. ESA

N89-20117# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
CONTINUOUS-DISCRETE FILTERING FOR SYSTEMS WITH MARKOVIAN SWITCHING COEFFICIENTS
H. A. P. BLOM 30 Oct. 1987 20 p Presented at the 21st Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, 2-4 Nov. 1987
(NLR-MP-87076-U; ETN-89-94046) Avail: NTIS HC A03/MF A01

The classical continuous-time linear system with Markovian switching coefficients is extended, to incorporate jumps in R sup n which occur simultaneously with coefficient switching. This system is defined by a stochastic differential equation in a hybrid space, which is driven by a Brownian motion and a Poisson random measure with a randomly time-changed mean measure. The exact continuous-discrete filter for such a system is approximated by a numerical algorithm, which is in its most simple form the interacting multiple model algorithm. For application to the problem of tracking a maneuvering aircraft, given measurements of uncertain origin, the obtained methods can easily be combined with probabilistic data association. ESA

N89-20119# Sandia National Labs., Albuquerque, NM. Exploratory Systems Development Div.
TRAJECTORY SCORING IN RECTANGULAR COORDINATES USING TRANSPONDER-INTERROGATOR RANGE AND RANGE RATE DATA
JEFF HOLLOWELL Jan. 1989 247 p
(Contract DE-AC04-76DP-00789)
(DE89-007005; SAND-87-1850) Avail: NTIS HC A11/MF A01

Range and range rate measurements taken from a transponder-interrogator ranging system are processed via an extended Kalman filter and an extended Kalman smoother to provide an accurate time-position history of a vehicle's trajectory by estimating the errors in the vehicle's inertial navigation system. The necessary equations are derived in rectangular coordinates. As such, they are only valid for low altitude flights over a small geographic area. The equations are implemented in a FORTRAN program which is used to process flight data gathered at Edgewood, NM. DOE

N89-20330*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DERIVING A GEOCENTRIC REFERENCE FRAME FOR SATELLITE POSITIONING AND NAVIGATION
R. P. MALLA (Sterling Software, Pasadena, CA.) and S.-C. WU *In its* The Telecommunications and Data Acquisition Report p 1-13 15 Nov. 1988
Avail: NTIS HC A12/MF A01 CSCL 17G

With the advent of Earth-orbiting geodetic satellites, nongeocentric datums or reference frames have become things of the past. Accurate geocentric three-dimensional positioning is now possible and is of great importance for various geodetic and oceanographic applications. While relative positioning accuracy of a few centimeters has become a reality using very long baseline interferometry (VLBI), the uncertainty in the offset of the adopted coordinate system origin from the geocenter is still believed to be on the order of 1 meter. Satellite laser ranging (SLR), however, is capable of determining this offset to better than 10 cm, but this is possible only after years of measurements. Global Positioning System (GPS) measurements provide a powerful tool for an accurate determination of this origin offset. Two strategies are discussed. The first strategy utilizes the precise relative positions that were predetermined by VLBI to fix the frame orientation and the absolute scaling, while the offset from the geocenter is determined from GPS measurements. Three different cases are presented under this strategy. The reference frame thus adopted will be consistent with the VLBI coordinate system. The second strategy establishes a reference frame by holding only the longitude of one of the tracking sites fixed. The absolute scaling is determined by the adopted gravitational constant (GM) of the Earth; and the latitude is inferred from the time signature of the Earth rotation in the GPS measurements. The coordinate system thus defined will be a geocentric Earth-fixed coordinate system. Author

N89-20331*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DETERMINATION OF GPS ORBITS TO SUBMETER ACCURACY
W. I. BERTIGER, S. M. LICHTEN, and E. C. KATSIGRIS *In its* The Telecommunications and Data Acquisition Report p 14-27 15 Nov. 1988
Avail: NTIS HC A12/MF A01 CSCL 17G

Orbits for satellites of the Global Positioning System (GPS) were determined with submeter accuracy. Tests used to assess orbital accuracy include orbit comparisons from independent data sets, orbit prediction, ground baseline determination, and formal errors. One satellite tracked 8 hours each day shows rms error below 1 m even when predicted more than 3 days outside of a 1-week data arc. Differential tracking of the GPS satellites in high Earth orbit provides a powerful relative positioning capability, even when a relatively small continental U.S. fiducial tracking network is used with less than one-third of the full GPS constellation. To demonstrate this capability, baselines of up to 2000 km in North America were also determined with the GPS orbits. The 2000 km baselines show rms daily repeatability of 0.3 to 2 parts in 10 to the 8th power and agree with very long base interferometry (VLBI) solutions at the level of 1.5 parts in 10 to the 8th power. This GPS demonstration provides an opportunity to test different techniques for high-accuracy orbit determination for high Earth orbiters. The best GPS orbit strategies included data arcs of at least 1 week, process noise models for tropospheric fluctuations, estimation of GPS solar pressure coefficients, and combine processing of GPS carrier phase and pseudorange data. For data arc of 2 weeks, constrained process noise models for GPS dynamic parameters significantly improved the situation. Author

N89-20977# General Accounting Office, Washington, DC.
MICROWAVE LANDING SYSTEMS: ADDITIONAL SYSTEMS SHOULD NOT BE PROCURED UNLESS BENEFITS PROVEN
May 1988 74 p
(GAO/RCED-88-118) Avail: NTIS HC A04/MF A01

Important parts of the national airspace system (NAS) are the precision landing systems which allow aircraft equipped with the necessary electronic hardware (avionics) to land in conditions of limited visibility, thereby increasing the time an airport can operate during poor weather. The current precision landing system, the instrument landing system (ILS), is scheduled to be replaced with the microwave landing system (MLS) as part of the Federal Aviation Administration's (FAA) effort to modernize the nation's air traffic control system-known as the NAS plan. The MLS program was reviewed, addressing the following objectives: assess the justification and requirements for a new precision landing system to replace ILS and determine and analyze ILS improvements since MLS was justified, determine whether FAA has adequately demonstrated MLS' potential operational and economic benefits, and determine the reasonableness of FAA'S MLS siting strategy. Author

N89-20978*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AH-1S COMMUNICATION SWITCH INTEGRATION PROGRAM
LORAN HAWORTH, ZOLTAN SZOBOSZLAY, ROBERT SHIVELY, and FRANK J. BICK (Army Aviation Systems Command, Saint Louis, MO.) Mar. 1989 62 p
(NASA-TM-101053; A-89005; NAS 1.15:101053; USAAVSCOM-TR-88-A-009) Avail: NTIS HC A04/MF A01 CSCL 17G

The C-6533/ARC communication system as installed on the test AH-1E Cobra helicopter was modified to allow discrete radio selection of all aircraft radios at the cyclic radio/intercommunication system switch. The current Cobra-fleet use of the C-6533 system is cumbersome, particularly during low-altitude operations. Operationally, the current system C-6533 configuration and design requires the pilot to estimate when he can safely remove his hand from an active flight control to select radios during low-altitude flight. The pilot must then physically remove his hand from the flight control, look inside the cockpit to select and verify the radio selection and then effect the selected radio transmission by activating the radio/ICS switch on the cyclic. This condition is potentially hazardous, especially during low-level flight at night in degraded weather. To improve pilot performance, communications effectiveness, and safety, manprint principles were utilized in the selection of a design modification. The modified C-6533 design was kept as basic as possible for potential Cobra-fleet modification. The communications system was modified and the design was subsequently flight-tested by the U.S. Army Aeroflightdynamics Directorate and NASA at the NASA Ames Research Center, Mountain View, California. The design modification enables the Cobra pilot to maintain hands-on flight controls while selecting radios during nap-of-the-Earth (NOE) flight without looking inside the cockpit which resulted in reduced pilot workload ratings, better pilot handling quality ratings and increased flight safety for the NOE flight environment. Author

N89-20980# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
AIRCRAFT TRACKING WITH DUAL TACAN M.S. Thesis

CHRISTOPHER J. MCCORMACK Dec. 1988 71 p (AD-A202647; AD-E900870; AFIT/GE/ENG/88D-28) Avail: NTIS HC A04/MF A01 CSCL 17G

This thesis addresses the problem of determining aircraft position during flight given noisy and biased measurements from a barometric altimeter and two tactical air navigation (TACAN) transceivers. A Kalman smoother is developed to perform post-flight data processing on the measurement data. The smoother estimates aircraft position, velocity, and acceleration as well as biases in the measurements. Since actual flight test data is not available, computer simulations examine the performance of this tracking technique. The simulated flight includes low and high-speed turns, constant rate ascents, descents, and accelerations. The tracking algorithm tracked the aircraft inertial navigation system used by the 4950th Test Wing in another flight test program that showed a position error growth rate of 2000 meters per hour. GRA

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A89-33139
APPLICATION OF HARMONIC ANALYSIS METHOD TO RESEARCH ON ROTOR AIRLOADS
ZHENHAN QIU, ZHENGZHONG XUE, and YUJIAN DUAN (Chinese Helicopter Research and Development Institute, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 1, July 1988, p. 63-70.

Following rotor-vortex theory, the rotor circulation and the rotor-induced velocity are developed into Fourier series. The circulation distribution along the blade (spanwise) is expressed in terms of segment-by-segment linear functions, and the induced-velocity equations and the circulation equations are derived. The induced velocity and its harmonic components are obtained to provide a quantitative basis for the vortex model. For calculating each harmonic component of the induced velocity a simplified method is put forward which saves computer time and is of significant benefit. Author

A89-33146
THE RELIABILITY ANALYSIS OF AIRCRAFT STRUCTURES
DEPEI ZHU (Northwestern Polytechnical University, Xian, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 1, July 1988, p. 117-122. refs

This paper presents a set of fundamental equations for reliability analysis of single-critical-point aircraft structures. The mathematical model is formulated by considering the following factors: the static strength of the structure; initial cracks, the initiation, propagation, and instability of fatigue cracks; the residual strength of the structure; the statistical distribution of the load; the periods of overhaul; accidental damage; the communication of damage among fleets; etc. Based on this mathematical model, the influence of these factors on the reliability can be quantitatively analyzed, and various criteria for fatigue design of aircraft structures can be evaluated from the aspect of reliability. Author

A89-33554
REMOTELY PILOTED VEHICLES; INTERNATIONAL CONFERENCE, 7TH, BRISTOL, ENGLAND, SEPT. 12-14, 1988, PROCEEDINGS AND SUPPLEMENTARY PAPERS
Conference sponsored by the Royal Aeronautical Society and University of Bristol. Bristol, England, University of Bristol, 1988, p. Proceedings, 173 p.; Supplementary Papers, 83 p. For individual items see A89-33555 to A89-33576.

The present conference on the development status and development prospects for RPVs discusses the U.S. Navy's unmanned air vehicle (UAV) program, U.S. Marine Corps RPVs for small-unit missions, the role of UAVs in the modern battlefield, the Sentinel and Sea Sentinel rotary-wing RPVs, the Skyeye and Phoenix complementary RPVs, the Falconet target RPV, civilian observation-platform applications of RPVs, and the Norton P37 rotary RPV engine. Also discussed are a computer-controlled system for multidrone flights, the development of a preliminary sizing method for UAVs, low cost avionics for UAVs, a low cost tracking/ranging system, RPV data links for video and IR surveillance, and aspects of the design of a naval RPV recovery system. O.C.

A89-33556
CANADAIR SENTINEL/SEA SENTINEL ROTARY WING RPV. IV
R. J. ATKINS and S. N. NASRY (Canadair, Inc., Montreal, Canada) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 5.1-5.15. refs

An evaluation is presented of the results obtained to date in the full-scale engineering development program of the CL-227 rotary-wing RPV, which in addition to the land-warfare applications for which it was originally conceived, and designated 'Sentinel', has been chosen as a candidate for naval development, to be designated 'Sea Sentinel'. The most recent development efforts have concentrated on the incorporation of a FLIR sensor, changes in ground control station design, and advanced methods for the display and manipulation of FLIR imagery. Attention is given to the problem posed by shipboard operations that must take into account ship motion and ship aerodynamic wake factors. O.C.

A89-33557
SOME ASPECTS OF THE DEVELOPMENT AND OPERATIONAL TESTING OF THE SPRITE SYSTEM
R. G. AUSTIN and C. C. PUGH (ML Aviation Co., Ltd., Maidenhead, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 7.1-7.15.

The Sprite military RPV is of helicopterlike, VTOL-capable configuration employing contrarotating coaxial main rotor blades and involving, in addition to the flight vehicle, a control console, a communications station, a terrestrial transport vehicle, and flight vehicle ground support equipment. After 8 years of development, Sprite has proven itself capable of fulfilling such varied requirements as those of the U.S. Army and Marine Corps for a close-range RPV, the RAF and USAF Damaged Airfield Information Reporting System, and the U.S. Navy's small naval vessel-deployable RPV system. The structural and mechanical components of the Sprite RPV are highly modular for ease of field maintenance and repair. O.C.

A89-33558
COMPLEMENTARY MINIS - SKYEYE AND PHOENIX, AN OVERVIEW OF THEIR MULTI-MISSION COVERAGE
R. W. DENNIS (GEC Avionics, Ltd., Flight Controls Div., Rochester, England), G. R. SEEMANN, G. L. HARRIS, and J. MAHON (Developmental Sciences Corp., Ontario, CA) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 8.1-8.10. Research supported by the Ministry of Defence Procurement Executive, DOD, and U.S. Army.

Despite their independent development, the Skyeye and Phoenix RPVs have been noted to share great commonality of approach to launch and recovery operations, flight control, and navigation. Attention is presently given to the prospects for simultaneous, coordinated, and complementary operations of the two systems from a common launcher and under the control of a common ground station. Phoenix is envisioned to operate in its primary role using Skyeye's cueing facility while flying at higher altitude with a SAR payload, or perhaps as a communications-relay platform. Skyeye is also expected to benefit from incorporation of such Phoenix subsystems as its thermal imager and digital map unit. O.C.

A89-33561
THE THETA BETA - DESIGN OF A SYSTEM
P. A. EUSTACE (Theta Analysis and Systems, Ltd., Aldershot, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 12.1-12.8.

Theta Beta is a prototype civil-applications unmanned air vehicle of modular design that can furnish a highly stable sensor platform with largely off-the-shelf technology. The modularity of the structure allows alternative configurations of the wing/buggy/payload to be chosen in order to best match a given application. The structure is transportable in two very compact parts; a permanently deployed 'quadricycle' undercarriage obviates ground-launch equipment. Both ground-based and autopilot control may be employed as required. Speed minimum and maximum are, respectively, 30 and 60 kts. O.C.

A89-33562
FLIGHT TEST OF XRAE-1 TO ESTABLISH AERODYNAMIC DATA
D. J. DYER (Cranfield Institute of Technology, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 13.1-13.8. Research supported by the Ministry of Defence Procurement Executive.

Flight test results are presented for the small unmanned aircraft designated XRAE-1, outfitted with two different wings, one of which was of conventional airfoil profile while the other employed a Wortmann FX63-137 profile. Attention was given to climb rate for a given airspeed, coefficient of lift for a given angle-of-attack, and coefficient of drag for the coefficient of lift achieved. Flight test and analysis methods employed are discussed, as are comparisons conducted between flight test results and those obtained for the two wings in wind tunnel tests. Good correlation was obtained. O.C.

A89-33564
THE DEVELOPMENT OF A PRELIMINARY SIZING METHOD FOR UNMANNED AIR VEHICLES
A. TURNBULL and J. P. FIELDING (Cranfield Institute of Technology, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 15.1-15.7. refs

The present multivariate optimization package-based sizing method for a wide variety of unmanned air vehicle configurations employs simple mass and drag estimation formulas for such airframe and systems components as the engine, fuselage, wing, electrical power and recovery systems. The total vehicle mass is then optimized with respect to the specific configurational variables of wing area and span, fuselage diameter, and engine thrust. The final results yield the vehicle's optimized mass. The baseline configuration mounts the turbojet powerplant beneath the fuselage, and employs conventional wings and empennage. O.C.

A89-33626#
TECHNOLOGY REQUIREMENTS FOR HYPERSONIC AIRBREATHING AIRCRAFT
D. DWOYER University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 59 p. refs

A comprehensive evaluation is made of the technology development status, development requirements, and technology integration problems associated with prospective hypersonic airbreathing aircraft design and construction efforts. Attention is given to the performance criteria that must be met by the variable-cycle powerplants under consideration and the primacy of scramjet propulsion, as well as to the intrinsic difficulties encountered in the integration of LH2 fuel's cryotankage requirements with a highly aerothermodynamically stressed vehicle primary structure. Both hypersonic-cruise and airbreathing spacecraft launch vehicle projects are considered. Results from tradeoff and optimization studies comparing various major alternative configurational types are presented. O.C.

A89-33705#
PREDICTION OF STRUCTURAL-ACOUSTIC RESPONSE OF AN AIRCRAFT FUSELAGE MODELED AS A PERIODIC STRUCTURE
HAMID JAMSHIDIAT and GAUTAM SENGUPTA (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 14 p. refs
(AIAA PAPER 89-1045)

An FEM scheme for predicting the natural modes of an aircraft fuselage immersed in an acoustic medium is developed and demonstrated. The complexity of the FEM model (and hence the computational cost) is reduced by applying the theory of periodic structures (PS) to large portions of the fuselage; the theoretical basis of this PS-FEM procedure is discussed in detail and illustrated with diagrams. Results for 15-bay steel cylinders with and without frame stiffeners are then presented in extensive tables and graphs and shown to be in good agreement with analytical solutions and full (non-PS) FEM predictions. The CPU time required for a typical computation is 9.59 sec with the PS-FEM, as compared to 269.5 sec with the full FEM. T.K.

A89-33706#
IN-FLIGHT EXPERIMENTS ON THE ACTIVE CONTROL OF PROPELLER-INDUCED CABIN NOISE
S. J. ELLIOTT, P. A. NELSON, I. M. STOTHERS, C. C. BOUCHER (Southampton, University, England), J. F. EVERS (British Aerospace, PLC, Manchester, England) et al. AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 6 p. Research supported by the Department of Trade and Industry of England. refs
(AIAA PAPER 89-1047)

Results are presented on flight trials of an experimental system for the active control of the harmonic sound field in the passenger cabin of a B.Ae. 748 twin turboprop aircraft with engines running at 14,200 rpm. The control system could adjust the output signals fed to up to 16 loudspeakers, placed at various positions within the cabin, to minimize the sum of the squares of the outputs of up to 32 microphones. The system was able to control the first three harmonics of the blade passage frequency simultaneously. The reductions achieved by the control system were found to be close to the optimum reductions achievable, as calculated using the measured primary pressures and transfer responses. I.S.

A89-33717*# Southwest Research Inst., San Antonio, TX.
INSTALLATION EFFECTS ON PROPELLER WAKE/VORTEX INDUCED STRUCTURE-BORNE NOISE TRANSMISSION
J. F. UNRUH (Southwest Research Institute, San Antonio, TX) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 8 p. refs
(Contract NAS1-17921)
(AIAA PAPER 89-1072)

A laboratory-based test apparatus was employed to investigate the effects of power-plant placement, engine/nacelle mass installation, and wing-to-fuselage attachment methods on propeller-induced structure-borne noise (SBN) transmission levels and their effects on noise-control measures. Data are presented showing SBN transmission is insensitive to propeller spanwise placement, however some sensitivity is seen in propeller-to-wing spacing. Installation of an engine/nacelle mass and variation in wing-to-fuselage attachments have measurable influences on SBN transmission and control measures. Author

A89-33719#
FULL-SCALE DEMONSTRATION TESTS OF CABIN NOISE REDUCTION USING ACTIVE VIBRATION CONTROL
M. A. SIMPSON, T. M. LUONG (Douglas Aircraft Co., Long Beach, CA), C. R. FULLER (Virginia Polytechnic Institute and State University, Blacksburg), and J. D. JONES (Purdue University, West Lafayette, IN) AIAA, Aeroacoustics Conference, 12th, San Antonio,

TX, Apr. 10-12, 1989. 7 p.
(AIAA PAPER 89-1074)

The results of tests conducted to demonstrate the effectiveness of active vibration control techniques in reducing structure-borne aircraft cabin noise are reported. A prototype active vibration control system is tested in a fuselage acoustic research facility using a 50-foot aft section of a DC-9 aircraft as the test article. Shakers attached to the engine pylon are used to simulate structure-borne vibrations which cause noise in the cabin. Active control forces are applied with shakers located in the aircraft interior and connected to the fuselage structure. The level and phase of the control forces are set by a PC-based control system, which is designed to minimize the average acoustic energy measured at selected locations in the aircraft cabin. The tests show good global reduction of interior noise levels and represent the benefits of active vibration control in full-sized aircraft. S.A.V.

A89-33720#
ADAPTIVE ACTIVE CONTROL OF ENCLOSED SOUND FIELDS IN ELASTIC CYLINDERS VIA VIBRATIONAL INPUTS
D. S. MANDIC and J. D. JONES (Purdue University, West Lafayette, IN) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(Contract NSF MSM-88-10384)
(AIAA PAPER 89-1075)

An active noise control system is evaluated using a simplified model of an aircraft fuselage. Horn drivers are used to simulate propeller-induced cabin noise while a mini-shaker attached pointwise to the shell wall is used as the control source. A single input/single output control system based on the filtered-x version of the least mean squares algorithm is used to optimize the signal of the control shaker. Control at three discrete frequencies corresponding to dominant acoustic cavity modes of the test shell is demonstrated, as well as control of two modes simultaneously. Global reductions as high as 28 dB of the interior acoustic field, with minimal increases in shell vibrations, are achieved. V.L.

A89-33721#
MODEL SIZE REQUIREMENTS FOR FINITE ELEMENT PREDICTION OF LOW-FREQUENCY CABIN NOISE AND VIBRATION
A. E. LANDMANN and H. F. TILLEMA (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 6 p. refs
(AIAA PAPER 89-1076)

Engine vibration transmitted with little attenuation through the airplane structure is a major source of LF cabin noise and vibration in advanced propeller aircraft. In order to design aircraft with lower interior noise and vibration levels, the use of the FEM to predict the dynamics characteristics of engine/airframe/acoustic-cavity systems has been studied. In this paper, the effort to define the required level of airframe structural modeling detail for acceptable predictions is discussed. The work presented covers the assumptions made in several model-size reduction schemes and a comparison of test data to the reduced model predictions. The reduced models studied include dynamic reduction of the empennage and vertical tail substrctures, representation of the shell structure aft of the rear spar with beams, and modeling of only the passenger cabin and strut-to-fuselage connections. Author

A89-33742#
SONIC FATIGUE-RESISTANT DAMPED LAMINATED STRUCTURES
CARL L. RUPERT (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) and RALPH E. TATE (LTV Corp., LTV Aircraft Products Group, Dallas, TX) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 8 p.
(AIAA PAPER 89-1102)

The sound pressure levels generated by aircraft jet engines can result in sonic fatigue of structure and damage to sensitive, on-board electronic gear. The program objective is to develop the passive damping technology required to achieve sonic fatigue resistance at reduced weight and to suppress structural vibration within aircraft equipment bays. The approach is to incorporate constrained layer damping into the fuselage and equipment racks as an integral part of their design, rather than to use less effective add-on damping treatment after the structure has been manufactured. The aft equipment bay of the B-1B aircraft was selected as the baseline component with which to compare and demonstrate the technology developed in this program. Author

A89-33743#
IDENTIFYING SONIC FATIGUE PRONE STRUCTURES ON A HYPERSONIC TRANSATMOSPHERIC VEHICLE (TAV)
P. J. POZEFSKY (McDonnell Douglas Corp., Saint Louis, MO) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 6 p. refs
(AIAA PAPER 89-1103)

A procedure was developed to identify areas of a large, hypersonic transatmospheric vehicle (TAV) that will be critical in sonic fatigue. This preliminary screening involved the application of simplified techniques to predict the acoustic loads and resulting local dynamic structural response on several areas of a typical TAV. The predicted responses were evaluated relative to basic high cycle fatigue data to determine susceptibility to the acoustic environment. Structures in several key areas show high acoustic response and warrant further investigation. Author

A89-33754*# Lockheed Aeronautical Systems Co., Burbank, CA.
INTERIOR NOISE IN THE UNTREATED GULFSTREAM II PROPFAN TEST ASSESSMENT (PTA) AIRCRAFT
H. L. KUNTZ and R. A. PRYDZ (Lockheed Aeronautical Systems Co., Kelly Johnson Research and Development Center, Burbank, CA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 9 p.
(Contract NAS3-24339)
(AIAA PAPER 89-1119)

Interior noise on the Gulfstream II Propfan Test Assessment (PTA) aircraft was measured using 19 wing, 22 fuselage, and 32 cabin-interior microphones to determine the sources of the cabin noise. Results from ground and flight test acoustic and vibration measurements and analyses show that the major source of cabin noise was the airborne propfan blade passage frequency tones. The radiated sound pressure levels and the richness of the harmonic content of the propfan increased with increasing altitude. The acoustic output of the propfan also depended on the shaft power, helical Mach number, and blade passage frequency. I.S.

A89-33755*# Douglas Aircraft Co., Inc., Long Beach, CA.
CABIN NOISE CONTROL GROUND TESTS FOR UHB AIRCRAFT
MYLES A. SIMPSON (Douglas Aircraft Co., Long Beach, CA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 11 p.
(Contract NAS1-18037)
(AIAA PAPER 89-1121)

Measurement and analysis procedures for cabin noise control ground tests conducted on a DC-9 aircraft test section are presented along with a summary of test results. These tests were designed to analyze the effectiveness of selected noise control treatments in reducing passenger cabin noise on aircraft with aft-mounted, advanced turboprop engines. The performance of various structural and cabin sidewall treatments is assessed, based on measurements of the resulting interior noise levels and fuselage acceleration levels under simulated advanced turboprop excitation. Author

A89-33757*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROPELLER MODELLING EFFECTS ON INTERIOR NOISE IN CYLINDRICAL CAVITIES WITH APPLICATION TO ACTIVE CONTROL
R. J. SILCOX and H. C. LESTER (NASA, Langley Research Center,

Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 13 p. refs
(AIAA PAPER 89-1123)

The coupling of a vibrating finite elastic cylinder and its interior cavity, closed with rigid end caps, is examined. Results are presented for several types of excitation including a point force, a single external acoustic monopole, and an array of external monopoles. Modal spectra are examined for a frequency range typical of the harmonic noise produced by advanced turbo-props. The effect of frequency and source distribution on modal content is presented. Significant interface modal filtering, which would have a beneficial impact on an active system for reducing interior noise, was found to occur for all cases. Some preliminary experimental data for a stiffened, composite cylinder are presented and discussed. Author

A89-33771*# McDonnell-Douglas Helicopter Co., Mesa, AZ.
IMPORTANCE OF ENGINE AS A SOURCE OF HELICOPTER EXTERNAL NOISE
R. D. JANAKIRAM, M. J. SMITH, and H. TADGHIGHI (McDonnell Douglas Helicopter Co., Mesa, AZ) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 14 p. refs
(Contract NAS1-17145)
(AIAA PAPER 89-1147)

A turboshaft engine's importance as a source of helicopter external noise is presently evaluated experimentally and analytically on the basis of test data from an MD500E helicopter, with and without engine muffler, during level flyovers and climbing flight. A strong engine noise component is noted for helicopter positions nearly overhead and beyond observed position, especially in the 200-1000 Hz range; its strong rearward directivity suggests the noise source to be the broadband exhaust or combustion noise radiated from the exhaust duct. The engine muffler furnished estimated perceived noise level reductions of 2-3 dB for the centerline. O.C.

A89-34509
TRANSIENT DYNAMICS OF AIRCRAFT PROPELLERS DURING TOUCH-DOWN IMPACT
Y. A. KHULIEF and H. T. CHIU (Alabama, University, Birmingham) Computers and Structures (ISSN 0045-7949), vol. 31, no. 3, 1989, p. 413-419. refs

The vibrational response of a rotating flexible structure to impulsive excitation is investigated analytically, applying a numerical dynamic-analysis scheme based on a multibody-system formulation. The generalized elastodynamic model and its realization for an aircraft propeller (modeled as a flexible beam) undergoing touchdown impact are derived, and results from a simulation of an entire light-aircraft/propeller configuration are presented in extensive graphs. The model is found to account for changes in blade response due to rotation-induced stiffness and the blade orientation at impact. T.K.

A89-34808#
SURFACE PRESSURE MEASUREMENTS ON A BODY SUBJECT TO VORTEX WAKE INTERACTION
A. G. BRAND, H. M. MCMAHON, and N. M. KOMERATH (Georgia Institute of Technology, Atlanta) AIAA Journal (ISSN 0001-1452), vol. 27, May 1989, p. 569-574. refs
(Contract DAAG29-82-K-0094)

Wind-tunnel experiments were conducted to examine the interaction effects between a rotor and idealized airframe in forward flight. Mean and unsteady pressures were measured on the airframe surface for various flight speeds. Strong rotor-wake interactions with the airframe create large excursions in the mean pressure distribution. Extreme fluctuations in the unsteady component of pressure are also observed. The flowfield features that cause these effects are identified and discussed. It is essential that a comprehensive aerodynamic interaction be obtained. Author

A89-34899#
STRUCTURAL OPTIMIZATION FOR AEROELASTIC CONTROL EFFECTIVENESS
M. KARPEL and Z. SHEENA (Israel Aircraft Industries, Ltd., Lod) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 493-495. refs

A wing structural optimization process such as that presently discussed attempts to achieve the targeted degree of structural effectiveness with minimum weight increase. A NASTRAN run for vibration modes which also creates a data base of element contributions to the generalized stiffness matrix is first performed; the major optimization cycle is divided into secondary cycles with intermediate targets. A preliminary version of the Lavi wing has been used to demonstrate the method, using antisymmetric boundary conditions. O.C.

A89-35196#
SPIN TESTING METHODS IN FLIGHT
J. P. DUVAL (Avions Marcel Dassault-Breguet Aviation, Istres, France) (National Seminar on Flight Research, Test and Development, Bangalore, India, Sept. 2, 3, 1987) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 159-166. Translation.

The principles of a spin test method are described together with the techniques involved and the individual steps of a field test of spin. Particular attention is given to the preliminary study in wind tunnel, the instrumentation of the aircraft in flight and on the ground, and the pilot's equipment. Results are presented on spin tests carried out on an Alpha Jet aircraft. I.S.

A89-35197#
DESIGNING WITH ADVANCED FIBROUS COMPOSITES
J. HART-SMITH (Douglas Aircraft Co., Long Beach, CA) (Workshop on New Materials and Process for Mechanical Design, Brisbane, Australia, May 1988) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 167-199. refs

The characteristics of advanced fibrous composites (carbon, boron, aramid, or glass in organic matrices) used by the aircraft industry in the U.S and Western Europe are discussed. Compared to metal alloys, fibrous composites have lower densities, higher specific strengths, lower manufacturing costs, virtually no corrosion, an improved surface finish, and the ability to make lower drag shapes more easily. In addition, fibrous composites make it possible to tailor laminate patterns for achieving desired stiffness and to manufacture dimensionally stable components with zero coefficient of expansion. Structural details of two 'all-composite' aircraft, the de Havilland Mosquito and the Lear Fan transport aircraft are discussed. Also discussed are some popular malpractices in advanced composite structures, the effects of joints on the design of composite structures, and the use of honeycomb sandwich type construction. I.S.

A89-35198#
DEVELOPMENT OF EXPERIMENTAL TECHNIQUES FOR HELICOPTER ROTOR PERFORMANCE STUDIES
S. R. PATIL (National Aeronautical Laboratory, Bangalore, India) and M. A. RAMASWAMY (Indian Institute of Science, Bangalore, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 40, Aug. 1988, p. 201-209. Research sponsored by the Aeronautical Research and Development Board. refs

The details of teetering rotor model and the associated strain gauge balance and calibration fixtures have been presented. Hovering results for 1.22 m diameter teetering rotor model evaluated experimentally have been compared with the simple blade element-momentum theory. Author

A89-35202#
HIGH PERFORMANCE ESCAPE CAPSULES
WILLIAM G. PICKL (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-6. refs
(AIAA PAPER 89-0878)

The extreme dynamic pressure environments of future supersonic and hypersonic cruise aircraft call for crew-escape

capsules of low weight and high performance. Improved design techniques and variable-geometry drogue chute stabilization subsystems are presently employed to reduce escape capsule weight, while gaining an active attitude-control capability and the possibility of ground-avoidance maneuvers. Retrorocket-firing is noted to be a promising method for the attenuation of landing-impact loads. Hypersonic drogue decelerator technologies are available that may be capable of initial operation at speeds of up to Mach 20. O.C.

A89-35205#
PILOT EJECTION FROM A PRONATED FLYING POSITION
ALLEN D. DISSELKOEN, KEITH H. HEISE (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH), ROBERT F. GARGIULO (USAF, Electronic Systems Div., Hanscom AFB, MA), and CURTIS H. SPENNY (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 24-33. refs
(AIAA PAPER 89-0885)

Aerodynamic and biomechanic analyses are presented for a fighter seat and escape system. A semi-enclosed seat configuration is described that provides pilot protection for ejections at a dynamic pressure of 2,000 psf, well beyond the capability of existing open-seat ejection systems. Increased ejection performance is achieved by taking advantage of a pronated (forward-leaning) seat configuration to: (1) increase pilot protection from windstream deceleration forces and (2) provide stability in the windstream prior to deployment of the drogue chute. These enhancements, in conjunction with the increased pilot g-tolerance during flight (described herein), make the concept of a pronated fighter seat very attractive. A computer model of pressure distribution on panels was used to predict aerodynamic forces and moments. Computer simulation of ejection dynamics was used to predict dynamic stability. Author

A89-35209#
TESTING OF A NEW RECOVERY PARACHUTE SYSTEM FOR THE F111 AIRCRAFT CREW ESCAPE MODULE - AN UPDATE
DONALD W. JOHNSON (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 47-52. refs
(Contract AF PROJECT SM-MMK-87-10-324;
DE-AC04-76DP-00789)
(AIAA PAPER 89-0891)

A new recovery parachute system has been designed for the F111 crew escape module (CEM). The system includes a cluster of three 49-ft-dia ringslot-solid parachutes, a Kevlar deployment bag, and an explosively fired drogue gun to deploy the pilot parachute. Tests have been conducted that indicate the parachute system will meet the rate of descent requirement of 25 ft/sec at 5000 ft pressure altitude. To control the drag load developed by the parachutes, a new central reefing/disreefing system has been developed. Since the recovery parachute system is normally deployed crosswind from the CEM, line sail of the suspension lines during early tests was a problem but has been minimized by a dual pilot parachute system. Author

A89-35299
LOAD ALLEVIATION ON TRANSPORT AIRCRAFT USING ACCELERATION FEEDBACK
A. BRADSHAW, T. RAHULAN, and M. A. WOODHEAD (Salford, University, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 701-706. refs

A theoretical concept for a flight controller was developed, which incorporates feedback of the rates of change of the state and output, making it possible to achieve gust-load alleviation on a transport aircraft. Noninteracting control equations were developed that yielded an integrated flight control system which can simultaneously alleviate gust-induced wing bending loads and control the aircraft in the pitch plane. Digital simulation results of a simple pitch-plane maneuver are presented to illustrate the tracking capabilities of the contoller. I.S.

A89-35825
NEW WINGS, NEW WAYS
Flight International (ISSN 0015-3710), vol. 135, March 18, 1989, p. 26-29.

The USSR's most recently revised unified airworthiness standards, to which such new aircraft as the four-engined, wide-body Il-96-300 airliner must adhere, follow the European safety-assessment practices developed over a decade ago. The maximum allowable probabilities of various potentially hazardous situations are determined for the aircraft as a whole, and acceptable probabilities are then derived for the failures of individual aircraft systems. Each system is, finally, assessed as a number of separate components. Efforts are also being made to reduce major maintenance for new aircraft in order to reduce the staffing levels required in heavy maintenance tasks. O.C.

A89-35842
CONTROLLING SEVERED HELICOPTER BLADES DURING EMERGENCY ESCAPE
GARY L. JARVIS and WILLIAM E. MCELRATH (Delta Technology Systems, Warminster, PA) SAFE Journal, vol. 19, Spring 1989, p. 26-33. refs

This paper presents a methodology for controlling the trajectories of the severed helicopter blades, thus reducing the hazard to other aircraft in close proximity, using the AH-1 Cobra as a model for the preliminary design of a blade deceleration system. Design concepts are presented for a modular self-contained fabric aerodynamic decelerator device mounted on each blade, which can be deployed by a simple mechanical action. The results of a trajectory study demonstrated that the use of this deceleration device results in a significant reduction in the flight. I.S.

A89-35843
ADVANCED RECOVERY SEQUENCER (ARS)
JAMES SCHOEN (Douglas Aircraft Co., Long Beach, CA) and KIT Q. BOYD (USAF, Wright-Patterson AFB, OH) SAFE Journal, vol. 19, Spring 1989, p. 34-41.

An Advanced Recovery Sequencer (ARS) has been developed for the ACES II ejection seat. The ARS uses digital microcontroller technology and solid state pressure transducers to optimize escape sequence timing. This is achieved by means of a continuously variable time delay for recovery parachute deployment under moderate-to-high-speed conditions.This is in contrast to the fixed delay provided by the current analog sequencer. The ARS will provide enhanced system reliability and maintainability through the use of built-in test capability. The ARS has completed subsystem qualification testing and is ready for system qualification testing. This paper presents an overview of the ARS program from conception through qualification. Author

N89-20121*# Illinois Univ., Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.
AEROSPACE VEHICLE DESIGN, SPACECRAFT SECTION FINAL PROJECT REPORTS
May 1988 344 p
(Contract NGT-21-002-080)
(NASA-CR-184741; NAS 1.26:184741; AAE-241-VOL-1) Avail: NTIS HC A15/MF A01 CSCL 01C

The objective was to create a manned Martian aircraft which can perform: scientific surveys of particular sites distant from the base; a deployment of scientific instrument packages by air drop that land rovers cannot accomplish; and rescue operations. Designing the airfoil requires a wing which can operate within the low Reynolds numbers apparent on Mars. The airfoil, NASA NLF(1)-1015 was chosen. The design of the aircraft is comparable to a P-38 military aircraft. The aircraft uses fuel cells to power the two propellers. A rocket-assisted takeoff is necessary to enable

Romulus to liftoff. Although the design and creation of Romulus would be an expensive adventure, such a vehicle could be most useful in evaluating the Mars surface and in creating a habitat for mankind. B.G.

N89-20122*# Illinois Univ., Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.
AEROSPACE VEHICLE DESIGN, SPACECRAFT SECTION FINAL PROJECT REPORTS
May 1988 354 p
(Contract NGT-21-002-080)
(NASA-CR-184742; NAS 1.26:184742; AAE-241-VOL-2) Avail: NTIS HC A16/MF A01 CSCL 01C

The next major step in the evolution of the space program is the exploration of the planet Mars. In preparation for this, much research is needed on the problem of surveying the planet surface. An aircraft appears to be a viable solution because it can carry men and equipment large distances in a short period of time as compared with ground transportation. The problems and design of an aircraft which would be able to survey the planet Mars are examined. Author

N89-20123*# Illinois Univ., Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.
AEROSPACE VEHICLE DESIGN, SPACECRAFT SECTION
May 1988 703 p
(Contract NGT-21-002-080)
(NASA-CR-184743; NAS 1.26:184743; AAE-241-VOL-3) Avail: NTIS HC A99/MF E03 CSCL 01C

Research results are presented for the following groups: Project Mars Airplane Vehicle and Reconnaissance Instrument Carrier (MAVRIC), ACME, ARES, Project ACRONYM, Mars Aircraft Recepticle with Technical Instruments, Aerobraking, and Navigation (MARTIAN), and NOMADS. Each project is described by the following areas of focus: mission planning and costs; aerobraking systems; structures and thermal control systems; attitude and articulation control systems; comman and data control systems; science instrumentation; and power and propulsion systems. B.G.

N89-20124*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
HUB AND BLADE STRUCTURAL LOADS MEASUREMENTS OF AN SA349/2 HELICOPTER
GLORIA K. YAMAUCHI, RUTH M. HEFFERNAN, and MICHEL GAUBERT (Societe Nationale Industrielle Aerospatiale, Marignane, France) Dec. 1988 136 p
(NASA-TM-101040; A-88300; NAS 1.15:101040) Avail: NTIS HC A07/MF A01 CSCL 01C

Data from 23 flight conditions, including level flights ranging from advance ratio mu = 0.14 to 0.37 and steady turning flights from advance ratio mu = 0.26 to 0.35, are presented for an Aerospatiale SA349/2 Gazelle helicopter. The data include hub loads data (for 6 of the 23 conditions), blade structural data at eleven different blade radial stations, and fuselage structural data. All dynamic data are presented as harmonic analysis coefficients (ten harmonics per rotor revolution). The data acquisition and reduction procedures are also documented. Blade structural and inertial properties are provided in addition to control system geometry and properties. Author

N89-20125*# Planning Research Corp., Hampton, VA. Aerospace Technologies Div.
ON THE RELATIONSHIP BETWEEN MATCHED FILTER THEORY AS APPLIED TO GUST LOADS AND PHASED DESIGN LOADS ANALYSIS
THOMAS A. ZEILER and ANTHONY S. POTOTZKY Apr. 1989 27 p Presented at the Gust Specialists Meeting, Mobile, AL, 6 Apr. 1989
(Contract NAS1-18000)
(NASA-CR-181802; NAS 1.26:181802) Avail: NTIS HC A03/MF A01 CSCL 01C

A theoretical basis and example calculations are given that demonstrate the relationship between the Matched Filter Theory approach to the calculation of time-correlated gust loads and Phased Design Load Analysis in common use in the aerospace industry. The relationship depends upon the duality between Matched Filter Theory and Random Process Theory and upon the fact that Random Process Theory is used in Phased Design Loads Analysis in determining an equiprobable loads design ellipse. Extensive background information describing the relevant points of Phased Design Loads Analysis, calculating time-correlated gust loads with Matched Filter Theory, and the duality between Matched Filter Theory and Random Process Theory is given. It is then shown that the time histories of two time-correlated gust load responses, determined using the Matched Filter Theory approach, can be plotted as parametric functions of time and that the resulting plot, when superposed upon the design ellipse corresponding to the two loads, is tangent to the ellipse. The question is raised of whether or not it is possible for a parametric load plot to extend outside the associated design ellipse. If it is possible, then the use of the equiprobable loads design ellipse will not be a conservative design practice in some circumstances. Author

N89-20126# National Aerospace Lab., Amsterdam (Netherlands). Structures and Material Dept.
MATCHING POWER SPECTRA DENSITY (PSD)-DESIGN LOAD
R. NOBACK 18 Aug. 1987 16 p Presented at the 65th AGARD Structures and Materials Panel and Flight of Flexible Aircraft in Turbulence Workshop, Cesme, Turkey, 4-9 Oct. 1987 Sponsored by The Netherlands Agency for Aerospace Programs, Delft, The Netherlands
(NLR-MP-87059-U; ETN-89-94040) Avail: NTIS HC A03/MF A01

It is shown that it is possible to generate equal probability design load conditions using power spectral density-design loads obtained with the design envelope criterion, and the correlation coefficients between these loads. The correlation coefficients can be calculated easily together with the A-values. The matrix of correlation coefficients can be used to define an N-dimensional surface. For the two-dimensional case this surface reduces to an ellipse. Each point on the surface defines an equal probability design load condition. It can be shown that such a condition is in equilibrium. Each design load condition can be used to calculate an estimate for the stress in a point of the structure. The method also can be used to generate design load conditions for the complete structure, for example the wing. A problem arises if stresses have to be calculated for a section of the structure for which the design values of the loads and the correlation coefficients were not calculated. It then seems logical to interpolate within a design load condition. This however leads to inconsistent Values of both loads and stresses in that section. The same problem arises in a discrete gust analysis if the design load conditions are defined as the loads occurring at the same time. A possible solution is to interpolate between the corresponding design loads and correlation coefficients of the adjoining sections. ESA

N89-20127# Rockwell International Corp., Columbus, OH. North American Aircraft Operations.
POWER EFFICIENT HYDRAULIC SYSTEMS. VOLUME 1: STUDY PHASE Final Report, Oct. 1985 - Jul. 1988
RICHARD V. HUPP and ROBERT K. HANING Jul. 1988 239 p
(Contract N62269-85-C-0259)
(AD-A203899; NA-88-0001-VOL-1; NADC-88066-60-VOL-1)
Avail: NTIS HC A11/MF A01 CSCL 13G

Energy saving concepts for aircraft hydraulic systems were studied in a two-phase program. Task 1 was an investigation of methods and techniques to reduce overall hydraulic system power requirements by lowering system demands and increasing component efficiencies. Task 2 involved hardware demonstration test on selected concepts. Task 1: Study Phase. A baseline hydraulic system for an advanced aircraft design was established. Twenty energy saving techniques were studied as candidates for application to the baseline vehicle. A global systems analysis approach was employed. The candidates were compared on the basis of total fuel consumption and six qualitative factors. Nine of

the most promising techniques were applied to a Target System . The target system had a 28 percent reduction in energy consumption and an 868 lb weight reduction over the baseline aircraft. GRA

N89-20128# Rockwell International Corp., Columbus, OH. North American Aircraft Operations.
POWER EFFICIENT HYDRAULIC SYSTEMS. VOLUME 2: HARDWARE DEMONSTRATION PHASE Final Report, Oct. 1985 - Jul. 1988
RICHARD V. HUPP and ROBERT K. HANING Jul. 1988 204 p (Contract N62269-85-C-0259)
(AD-A203900; NA-88-0001-VOL-2; NADC-88066-60-VOL-2)
Avail: NTIS HC A10/MF A01 CSCL 13G

Energy saving concepts for aircraft hydraulic systems were studied in a two-phase program. Task 1 was an investigation of methods and techniques to reduce overall hydraulic system power requirements by lowering system demands and increasing component efficiencies. Task 2 involved hardware demonstration tests on selected concepts. Hardware demonstration phase. Two techniques demonstrated for energy savings were control valves with overlap and dual pressure level systems. Tests were conducted on control valves, a servo actuator, dual pressure pumps, and a lightweight hydraulic system simulator. Valves with 0.002 in. overlap reduced system energy consumption 18 percent compared to using valves with zero lap. Operation at 4000 psi reduced system energy consumption 53 percent compared to operation at 8000 psi. Pressure level switching was accomplished with good results. GRA

N89-20945*# Grumman Aerospace Corp., Bethpage, NY. Aircraft Systems Div.
METHOD TO PREDICT EXTERNAL STORE CARRIAGE LOADS AT TRANSONIC SPEEDS
BRUCE S. ROSEN *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 453-465 Mar. 1989 Previously announced in IAA as A88-22003
(Contract NAS1-18105)
Avail: NTIS HC A22/MF A01 CSCL 01C

A computational method for prediction of external store carriage loads at transonic speeds is described. The geometric flexibility required for treatment of isolated and underwing, pylon mounted stores is achieved by computing solutions on a five level embedded grid arrangement. A completely automated grid generation procedure facilitates applications. Store modeling capability consists of bodies of revolution with multiple fore and aft fins. A body conforming grid improves the accuracy of the computed store body flow field. A nonlinear finite difference relaxation scheme, developed specifically for modified transonic small disturbance flow equations, enhances numerical stability and accuracy. As a result, more accurate treatment of low aspect ratio, highly swept and tapered wing planforms is possible. A limited supersonic freestream capability is also provided. Pressure, load distribution, force and moment correlation show good agreement for several test cases. Author

N89-20946*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STEADY AND UNSTEADY TRANSONIC SMALL DISTURBANCE ANALYSIS OF REALISTIC AIRCRAFT CONFIGURATIONS
JOHN T. BATINA, DAVID A. SEIDEL, ROBERT M. BENNETT, HERBERT J. CUNNINGHAM, and SAMUEL R. BLAND *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 467-496 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 01C

A transonic unsteady aerodynamic and aeroelastic code called CAP-TSD (Computational Aeroelasticity Program - Transonic Small Disturbance) was developed for application to realistic aircraft configurations. It permits the calculation of steady and unsteady flows about complete aircraft configurations for aeroelastic analysis of the flutter critical transonic speed range. The CAP-TSD code uses a time accurate approximate factorization algorithm for solution of the unsteady transonic small disturbance potential equation. An overview is given of the CAP-TSD code development effort along with recent algorithm modifications which are listed and discussed. Calculations are presented for several configurations including the General Dynamics 1/9th scale F-16C aircraft model to evaluate the algorithm and hence the reliability of the CAP-TSD code in general. Calculations are also presented for a flutter analysis of a 45 deg sweptback wing which agree well with the experimental data. Descriptions are presented of the CAP-TSD code and algorithm details along with results and comparisons which demonstrate the stability, accuracy, efficiency, and utility of CAP-TSD. Author

N89-20947*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INVERSE WING DESIGN IN TRANSONIC FLOW INCLUDING VISCOUS INTERACTION
LELAND A. CARLSON, ROBERT R. RATCLIFF, THOMAS A. GALLY (Texas A&M Univ., College Station.), and RICHARD L. CAMPBELL *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 497-519 Mar. 1989
(Contract NSG-1619)
Avail: NTIS HC A22/MF A01 CSCL 01C

Several inverse methods were compared and initial results indicate that differences in results are primarily due to coordinate systems and fuselage representations and not to design procedures. Further, results from a direct-inverse method that includes 3-D wing boundary layer effects, wake curvature, and wake displacement are represented. These results show that boundary layer displacements must be included in the design process for accurate results. Author

N89-20981*# California Univ., Los Angeles. School of Engineering and Applied Science.
HYPERSONIC DRONE DESIGN: A MULTIDISCIPLINARY EXPERIENCE
Jun. 1988 302 p
(Contract NGT-21-002-080)
(NASA-CR-184740; NAS 1.26:184740) Avail: NTIS HC A14/MF A01 CSCL 01C

Efforts were focused on design problems of an unmanned hypersonic vehicle. It is felt that a scaled hypersonic drone is necessary to bridge the gap between present theory on hypersonics and the future reality of the National Aerospace Plane (NASP) for two reasons: to fulfill a need for experimental data in the hypersonic regime, and to provide a testbed for the scramjet engine which is to be the primary mode of propulsion for the NASP. Three areas of great concern to NASP design were examined: propulsion, thermal management, and flight systems. Problem solving in these areas was directed towards design of the drone with the idea that the same design techniques could be applied to the NASP. A seventy degree swept double delta wing configuration, developed in the 70's at NASA Langley, was chosen as the aerodynamic and geometric model for the drone. This vehicle would be air-launched from a B-1 at Mach 0.8 and 48,000 feet, rocket boosted by two internal engines to Mach 10 and 100,000 feet, and allowed to cruise under power of the scramjet engine until burnout. It would then return to base for an unpowered landing. Preliminary energy calculations based upon the flight requirements give the drone a gross launch weight of 134,000 lb. and an overall length of 85 feet. Author

N89-20982*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED AERODYNAMIC/DYNAMIC OPTIMIZATION OF HELICOPTER ROTOR BLADES
ADITI CHATTOPADHYAY, JOANNE L. WALSH, and MICHAEL F. RILEY (Planning Research Corp., Hampton, VA.) Feb. 1989 15 p Presented at the 30th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-5 Apr. 1989
(NASA-TM-101553; NAS 1.15:101553; AIAA-89-1269) Avail: NTIS HC A03/MF A01 CSCL 01C

An integrated aerodynamic/dynamic optimization procedure is used to minimize blade weight and 4 per rev vertical hub shear for a rotor blade in forward flight. The coupling of aerodynamics and dynamics is accomplished through the inclusion of airloads which vary with the design variables during the optimization process. Both single and multiple objective functions are used in the optimization formulation. The Global Criteria Approach is used to formulate the multiple objective optimization and results are compared with those obtained by using single objective function formulations. Constraints are imposed on natural frequencies, autorotational inertia, and centrifugal stress. The program CAMRAD is used for the blade aerodynamic and dynamic analyses, and the program CONMIN is used for the optimization. Since the spanwise and the azimuthal variations of loading are responsible for most rotor vibration and noise, the vertical airload distributions on the blade, before and after optimization, are compared. The total power required by the rotor to produce the same amount of thrust for a given area is also calculated before and after optimization. Results indicate that integrated optimization can significantly reduce the blade weight, the hub shear and the amplitude of the vertical airload distributions on the blade and the total power required by the rotor. Author

N89-20983*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SIMULATION AT DRYDEN FLIGHT RESEARCH FACILITY FROM 1957 TO 1982
JOHN P. SMITH, LAWRENCE J. SCHILLING, and CHARLES A. WAGNER Feb. 1989 14 p Presented at the SES/SFTE Simulation-Aircraft Test and Evaluation Symposium, Patuxent River, MD, 16-17 Mar. 1982
(NASA-TM-101695; H-1530; NAS 1.15:101695) Avail: NTIS HC A03/MF A01 CSCL 01C

The Dryden Flight Research Facility has been a leader in developing simulation as an integral part of flight test research. The history of that effort is reviewed, starting in 1957 and continuing to the present time. The contributions of the major program activities conducted at Dryden during this 25-year period to the development of a simulation philosophy and capability is explained. Author

N89-20984# Air Force Occupational and Environmental Health Lab., Brooks AFB, TX.
CONTAMINATION OF THE EXTERIOR OF A C-130E AIRCRAFT USED FOR AERIAL SPRAY, 907 TAG, RICKENBACKER ANGB, OH Final Report
THOMAS H. LILLIE Sep. 1988 14 p
(AD-A202430; USAFOEHL-88-137EQ0110JEF) Avail: NTIS HC A03/MF A01 CSCL 15F

Contamination of the exterior of a C-130E aircraft was evaluated during flight tests of a new modular aerial spray system at Dobbins AFB, GA and Avon Park AFR, FL. Oil sensitive cards and paper index cards were taped to 50 sites on the exterior of the aircraft to monitor deposition of Dibrom, Malathion, soybean oil, and water during aerial spray operations. Light contamination of the aileron occurred when the wing booms were used and heavy contamination of the cargo door and horizontal stabilizer occurred when the fuselage booms were used. GRA

N89-20985# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
PERFORMANCE ANALYSIS OF THE FIBER DISTRIBUTED DATA INTERFACE IN THE SUPER COCKPIT AUDIO WORLD M.S. Thesis
JUANCHO E. FORLANDA Dec. 1988 288 p
(AD-A202535; AFIT/GCS/ENG/88D-6) Avail: NTIS HC A13/MF A01 CSCL 12G

The purpose of this thesis was to determine if the Fiber Distributed Data Interface (FDDI) network, a 100 Mbps fiber optic ring network, could satisfy the networking requirement (to support up to 130 terminals) of the Super Cockpit Audio World. To help make this determination a computer simulation was created to model the FDDI network and the load that may be created by several audio world terminals on that network. The simulation model used the mean token rotation time (TRT) in combination with a specified target TRT (TTRT) as the performance parameter of interest. The TRT responses of FDDI were observed for cases where all terminals used 16-bit PCM, 5-bit ADPCM, CVSD, or LPC (packetized to 4096, 16384, or 35904 bits; for 50, 100, 130, and 150 stations) with or without silence suppression to the audio signals begin transmitted. The simulation results (the TRT responses) revealed that FDDI can support 130 audio terminals using 16-bit PCM; however, it cannot support 150 audio terminals. When silence suppression is applied, FDDI is able to support the same 150 terminals with less than a 2 percent probability that an audio packet would be late for play out on a receiving audio terminal. The simulation results also showed that at least 150 terminals using 5-bit ADPCM, CVSD, or LPC with or without silence suppression could be accommodated by FDDI. GRA

N89-20986# Air War Coll., Maxwell AFB, AL.
INCORPORATING FIVE NATIONS' OPERATIONAL REQUIREMENTS INTO A SINGLE AIRCRAFT: THE F-16 MULTINATIONAL FIGHTER PROGRAM VIEWED FROM THE OPERATIONAL SIDE
EINAR SMEDSVIG Apr. 1988 62 p
(AD-A202552) Avail: NTIS HC A04/MF A01 CSCL 05A

Remarks on the background for the F-16 multinational program introduce a detailed discussion of the operational facets of the total program. A description of the operational organizations follows to complete the background for the author's views on the importance of the international participation in the F-16 program. After a discussion of how the international participation improved the F-16 operational dialogue has improved interoperability and cooperation beyond the original F-16 program. Lessons learned and potential future applications are discussed. GRA

N89-20987# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
PRELIMINARY DESIGN OF A MODULAR UNMANNED RESEARCH VEHICLE. VOLUME 1: SYSTEM DESIGN DOCUMENT M.S. Thesis
CHRISTOPHER D. HALL, RICHARD L. JOHNSON, PETER J. LAMATSCH, DOUGLAS A. MCCABE, PAUL J. MUELLER, III, MICHAEL E. PAUL, and LETITIA M. POHL Dec. 1988 215 p
(AD-A202765; AFIT/GSE/AA/88D-2-VOL-1) Avail: NTIS HC A10/MF A01 CSCL 01C

This thesis presents the analysis and development of a modular unmanned research vehicle (MURV) to support aeronautical research for AFIT. The MURV is proposed as a test vehicle to permit experimental efforts beyond the restrictions of pure analytical and wind tunnel research, yet less costly and more accessible than full-scale flight tests. A classical systems approach was applied in concert with a conventional aircraft design process which emphasized system level needs and objectives in the design of MURV subsystems. The primary design drivers were the need for adequate data acquisition for anticipated experiments, structural and functional modularity to permit simple reconfiguration, and focus on a set of unique experiments relating to fighter-like supermaneuverability. The supermaneuverability experiments dictated that the general arrangement of the MURV baseline design would resemble a typical modern fighter aircraft configuration, the recommended baseline being a turbojet-powered delta wing design with canards, single vertical tail, and control-configured ventral fins. Modularity implications resulted in the design of a flexible, digital flight control system with primary functions distributed between the vehicle and a remote pilot/control ground station, and a fuselage design which allows for relocation and replacement of wings and tails or canards. The data acquisition system is fully integrated with the flight control system and the remote ground station. The MURV is capable of flight speeds approaching 260 knots for altitudes up to 20,000 feet, and has fuel to fly for well over 30 minutes. GRA

N89-20988# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
A WIND TUNNEL AND COMPUTER INVESTIGATION OF THE LOW SPEED AERODYNAMIC CHARACTERISTICS OF THE PRONE ESCAPE SYSTEM (PRESS) M.S. Thesis
LONNIE R. DILLON Dec. 1988 104 p
(AD-A202768; AFIT/GAE/AA/88D-09) Avail: NTIS HC A06/MF A01 CSCL 01A

Due to new design technology, future jet fighters will fly at higher g levels than before. A previous preliminary design study was conducted to develop an ejection seat providing higher g-tolerance for the crewmember during maneuvering as well as improved windblast protection during ejection. This seat used the crewmember in a prone, or leaning forward, position. The Prone Ejection System was computer simulated at supersonic conditions in the earlier report and found satisfactory. It was the purpose of this present research to perform an experimental low speed study of the aerodynamic characteristics of the PRESS. Wind tunnel testing was performed to determine the static stability of the PRESS and measure pressures over the seat. It was determined that static pitch stability did not occur at the desired angle of attack, but could be easily corrected with aerodynamic fins and/or a shift in the center of gravity. Directional stability was also confirmed. An analytical experiment was also performed to determine whether a potential paneling code could be modified to predict flow conditions about the PRESS. An apparent body was constructed by including the regions of flow separation as part of the seat itself. Water tunnel flow visualization was used to determine the shape of the apparent body. The computer analysis showed that a paneling code could accurately predict the pressure coefficients on the cowling. GRA

N89-20989# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
RESPONSE EQUIVOCATION ANALYSIS FOR THE SMART STICK CONTROLLER M.S. Thesis
JOHN M. PRACHER Nov. 1988 148 p
(AD-A203146; AFIT/GE/ENG/88D-38) Avail: NTIS HC A07/MF A01 CSCL 01D

This thesis provides an analysis of response equivocation (lost information) for subjects who use the smart stick controller -- an aircraft stick controller designed by the Armstrong Aerospace Medical Research Laboratory (AAMRL) to improve a pilot's tracking performance. First, a control theory model of a compensatory tracking task is developed and analyzed. Then, using an information theory model of the pilot, the results are used to develop expressions for information theory parameters (input entropy, transinformation, and equivocation). Six subjects were tested using the smart stick controller and experimental an apparatus developed by the AAMRL. Each subject was tested twice: first in the passive stick mode (normal stick operation), and again in the active stick mode. In the active stick mode, the smart stick actively exerts a force in the direction opposite to the desired stick motion. Power spectral densities of the display error and the operator response were used to calculate the information theory parameters. GRA

N89-20990# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.
NONLINEAR ROTORCRAFT ANALYSIS-EXPERIMENTAL AND ANALYTICAL Final Report, 15 Sep. 1985 - 14 Jan. 1989
BENSON H. TONGUE 13 Nov. 1988 8 p
(Contract DAAG29-85-K-0207)
(AD-A203967; ARO-22557.5-EG) Avail: NTIS HC A02/MF A01 CSCL 01C

A parallel effort involving both analytical and experimental work was performed to allow a deeper understanding of the limit cycle behavior of rotorcraft and of the implication of this behavior for the safe operation of such rotorcraft. The theoretical development encompassed articulated and hingeless rotors with a great enough number of included degrees of freedom to allow accurate predictions of a simplified rotorcraft's responses. The experimental model allowed the simulation of both hingeless and articulated rotors in ground resonance. The purpose of the above work was to identify the regimes of helicopters operation that can support limit cycling and the range of excitations the system can withstand before entering a limit cycle. GRA

N89-20991*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AEROELASTIC MODELING FOR THE FIT TEAM F/A-18 SIMULATION
THOMAS A. ZEILER and CAROL D. WIESEMAN Mar. 1989 19 p Presented at the 2nd NASA/AF Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, Hampton, VA, Sep. 1988
(NASA-TM-101569; NAS 1.15:101569) Avail: NTIS HC A03/MF A01 CSCL 01C

Some details of the aeroelastic modeling of the F/A-18 aircraft done for the Functional Integration Technology (FIT) team's research in integrated dynamics modeling and how these are combined with the FIT team's integrated dynamics model are described. Also described are mean axis corrections to elastic modes, the addition of nonlinear inertial coupling terms into the equations of motion, and the calculation of internal loads time histories using the integrated dynamics model in a batch simulation program. A video tape made of a loads time history animation was included as a part of the oral presentation. Also discussed is work done in one of the areas of unsteady aerodynamic modeling identified as needing improvement, specifically, in correction factor methodologies for improving the accuracy of stability derivatives calculated with a doublet lattice code. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A89-33148
DESIGN OF AN AIRBORNE OPTIC FIBER DATA BUS SYSTEM
RENZHOU FAN, GONGHAO WANG, and RUILIN CHEN (Beijing University of Aeronautics and Astronautics, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 1, July 1988, p. 128-137. refs

The development, application, communication protocol, and system structure of an airborne data-bus system are discussed. The emphasis is on the design of the hardware, software, and fiber-optic transmission system of the bus controller and remote terminal. Some experiments and their results are also given. Author

A89-33571
LOW COST AVIONIC SYSTEM FOR UMA
S. E. UWINS (Skyleader Radio Control, Ltd., Croydon, England) and D. W. ALLEN IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 19.1-19.4.

The desirable features and capabilities of avionics suites applicable to both civil and military reconnaissance unmanned aircraft (UMA) are discussed. The XRAE1 UMA test vehicle was initially outfitted with a commercial anemometer-based airspeed sensor and an angle-of-attack sensor, for comparative testing; in order to furnish additional damping in pitch, an angular rate gyro was incorporated. The result was the Skyleader 8409 low cost UMA avionics system, whose capacity for further development is presently related. O.C.

A89-33574
LINESCAN 2000 - TOMORROW'S SENSOR TODAY
T. M. STEPHENS (British Aerospace, PLC, Hatfield, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol,

England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 23.1-23.4.

The range of considerations pertinent to the design of a payload for reconnaissance RPV applications is illustrated by the case of the 'Linescan 2000' IR imaging system's design constraints, which encompass high reliability and maintainability, modularity, and the minimization of scheduled servicing. Linescan 2000, which occupies an RPV payload volume of only 0.02 cu m, achieves high resolution and a wide field-of-view with a configuration that entails a minimum of onboard signal processing. Proven modular components are employed, significantly reducing development costs. O.C.

A89-34443
AVIATION DISPLAYS
ALAN F. STOKES (Illinois, University, Savoy) and CHRISTOPHER D. WICKENS (Illinois, University, Champaign) IN: Human factors in aviation. San Diego, CA, Academic Press, Inc., 1988, p. 387-431. Research supported by General Motors Corp. refs

The design principles and characteristics of state-of-the-art cockpit displays are reviewed from the perspective of human-factors engineering. Topics addressed include flight-path displays (quickening and predictive displays), navigational displays, display organization and configuration, the visual overload problem, head-up displays, peripheral displays, speech and nonspeech auditory displays, color displays, advanced cockpits, and display automation (decluttering and reconfiguration). Drawings, diagrams, and photographs of typical displays are provided. T.K.

A89-34446
COCKPIT-CREW SYSTEMS DESIGN AND INTEGRATION
GEORGE A. SEXTON (Lockheed-Georgia Co., Advanced Design Dept., Marietta) IN: Human factors in aviation. San Diego, CA, Academic Press, Inc., 1988, p. 495-526. refs

Recent advances in transport-aircraft cockpit design are reviewed from the perspective of human-factors engineering. The early evolution of the cockpit is recalled; the relationship between design and crew workload is explored; and the design philosophies and actual display and control systems of state-of-the-art cockpits are discussed in detail and illustrated with extensive photographs. Particular attention is given to computerization, head-down and head-up displays, fly-by-wire systems, control technology, data links, lighting, the crew-systems design process itself (mission analysis and mission scenarios, hardware design, mockup studies, and testing by experienced aircrews), and system integration. The impact of new designs on physical and cognitive workloads, aircraft certification, and personnel policies is briefly characterized. T.K.

N89-20129# National Aerospace Lab., Amsterdam (Netherlands). Hoofdafdeling: Vliegtuigen.
ELECTRONICS IN CIVIL AVIATION
F. J. ABBINK 5 Nov. 1987 20 p In DUTCH; ENGLISH summary Presented at the KIVI-NIRIA Symposium on Electronics in Aerospace, Utrecht, The Netherlands, 5 Nov. 1987
(NLR-MP-87009-U; ETN-89-94031) Avail: NTIS HC A03/MF A01

The development of the electronic systems which are used in airliners for communication, navigation, identification, flight control, engine control, for the acquisition and presentation of flight and system data, as well as for air traffic control is reviewed. The development of these systems was made possible by developments in microelectronics, computer technology, and display technology. Developments in electronics systems in civil aviation, as fly-by-wire, full authority digital engine control, satellite navigation, satellite communication, and the microwave landing system, and their implications on future air traffic control are considered. ESA

N89-20130# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
THE DATA ACQUISITION SYSTEM FOR THE FOKKER 100 TEST AIRCRAFT
S. STORM VANLEEUWEN and A. VOSKES (Fokker B.V., Amsterdam, Netherlands) 28 Jul. 1987 15 p Presented at the 18th Annual Flight Test Engineers Symposium, Amsterdam, The Netherlands, 2 Oct. 1987 Previously announced in IAA as A88-51465
(NLR-MP-87047-U; ETN-89-94036) Avail: NTIS HC A03/MF A01

The data acquisition system for the Fokker 100 test aircraft (capability, electrical lay-out, real time presentation facilities, and performance parameters) is described. The take-off and landing performance measuring system and the automatic noise measuring system are highlighted. It was decided to keep the data acquisition systems for both test aircraft identical. The savings on the design costs and the possibility of using each aircraft for most of the flight tests counterbalance the extra cost in instrumentation. The data acquisition systems perform to specification. ESA

N89-20993# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
REAL-TIME DISPLAY OF TIME DEPENDENT DATA USING A HEAD-MOUNTED DISPLAY M.S. Thesis
GARY K. LORIMOR Dec. 1988 64 p
(AD-A203051; AFIT/GE/ENG/88D-22) Avail: NTIS HC A04/MF A01 CSCL 25C

The purpose of this investigation was the development of a software system to integrate time-dependent data with a three-dimensional virtual environment. Red Flag data tapes were used as a source of time-dependent data. To project this into a virtual environment a head-mounted display was used. The software development was done on a Silicon Graphics Iris 3130 workstation. The design of the software system allows the user to be free of the keyboard for most situations. The position of the user's head was determined using a Polhemus 3-space tracker. The user could exercise basic control of the system with input from mouse buttons. The user was allowed to move to any position in the environment by looking in the direction of desired travel. The user was also given the option to ride in any cockpit which was in the environment. This allowed the user to see the environment from a pilots perspective at a specific point and time in the display sequence. Minimal machine dependent routines were used in the development of the software system. The software system was developed using the C programming language. The results of this effort were encouraging. There appears to be further possibilities of use for a system of this type in the training arena. The update rate of this system is about 10 frames per second. There appears to be several open questions concerning the benefits of such a system in the training environment. GRA

N89-20994# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
A HELMET-MOUNTED VIRTUAL ENVIRONMENT DISPLAY SYSTEM M.S. Thesis
ROBERT KEITH REBO Dec. 1988 87 p
(AD-A203055; AFIT/GCS/ENG/88D-17) Avail: NTIS HC A05/MF A01 CSCL 25C

This effort researches existing Helmet Mounted Display (HMD) systems and presents a prototype design of a color Helmet-Mounted Virtual Environment Display System. Many existing systems are discussed, including systems currently in use by the U.S. Navy, Air Force, and Army. Several differing designs are presented and evaluated. The Air Force Institute of Technology Helmet Mounted Virtual Environment Display System places the user in a visual situation that is generated by a computer. This HMD system could easily be adapted for use with a video camera. This paper presents an inexpensive system design that incorporates the benefits of other efforts. The cost trade offs are evaluated and the best design for the lowest cost is presented. The optics, three dimensional considerations, the mounting platform and display technologies are also discussed. The final HMD system design is described in detail and presented so that any reader could build a similar system for minimal cost. This system uses color Liquid Crystal Displays (LCD) mounted directly before the eyes of the user. Specially designed optics were developed to enable the user to focus on the image only inches away. The positional information of the user is determined by a sensitive electro-magnetic device developed by Polhemus Navigational

Sciences. This system is very accurate but has a limited effective range. Predictive tracking is discussed and implemented using a simple Kalman filter equation. GRA

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A89-33386#
3-D LDA-MEASUREMENTS IN THE JET OF A BYPASS-ENGINE
D. PALLEK, K.-H. SAUERLAND, K. A. BUETEFISH (DFVLR, Institut fuer experimentelle Stroemungsmechanik, Goettingen, Federal Republic of Germany), H.-J. ROSCHER, and H. HOHEISEL (DFVLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 4.13 (6 p.). refs

The present contribution describes measurements obtained with a three-component LDA (focal length 2.3 m) within the propulsive jet of a real fan engine (RR M45 H) in an engine test bed. The aerodynamic data obtained at the fan exit, at the turbine nozzle exit, and downstream of the nozzle plug give insight into the propulsive jet behavior without external flow for an off-design condition. The velocity components in the specified positions for all three coordinate directions are discussed, allowing the evaluation of the radial distributions and the swirl components. In addition, the important parameters of the turbulence in the jet are presented. Author

A89-33485
METALLIC LIMITATIONS IN AIRCRAFT ENGINES - THE RATIONAL RETURN TO THE STONE AGE
G. W. MEETHAM (Rolls Royce, PLC, Derby, England) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 38.1-38.6.

The current development status of materials for high-temperature applications in advanced gas-turbine engines is surveyed. Topics discussed include Ni-based superalloys for turbine airfoils, corrosion-resistant coatings, directional solidification, single-crystal technology, mechanical alloys, and blade cooling methods. Consideration is given to film cooling techniques for combustors, oxidation-resistant superalloys for combustors, and the future potential of SiC and Si3N4 components (assuming that their reliability can be demonstrated). T.K.

A89-33565
THE NORTON P73 ROTARY RPV ENGINE
C. J. BIDDULPH (Norton Motors, Ltd., Lichfield, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 16.1-16.8.

The development history, design features and performance capabilities of the P73 RPV engine are presented. The P73 is a Wankel-type rotary engine based on extensive experience with motorcycle motors, but incorporating ram air cooling and ultralightweight structural design to meet the performance requirements of target-drone RPVs. The use of ram-air cooling has obviated intercoolers and exhaust ejectors. The engine is able to produce 26 bhp despite a weight of only 22 lbs, and has met all requirements of the Joint Air Regulations 22.1849, which is the European test standard for motor-glider and sailplane engines. O.C.

A89-33570
EVOLUTION OF A SMALL TURBINE ENGINE FAMILY FOR UNMANNED AERIAL VEHICLES
J. POWELL (Williams International, Walled Lake, MI) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 17.1-17.6.

An account is given of the development history for a family of small, flightweight, expendable gas turbine engines applicable to many typical unmanned air vehicles' turboshaft requirements, including those of the CL-227 VTOL Sentinel contrarotating rotary-wing propulsion system. An exhaust heat recuperator may be incorporated in order to improve fuel consumption by as much as 45 percent and to reduce exhaust IR emissions, as required to improve tactical survivability. One engine family member is also applicable to turboshaft primary power unit requirements. O.C.

A89-33769#
ACOUSTIC CHARACTERISTICS OF COUNTERROTATING FANS FROM MODEL SCALE TESTS
B. A. JANARDAN and P. R. GLIEBE (General Electric Co., Cincinnati, OH) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 14 p. refs
(AIAA PAPER 89-1142)

The noise characteristics of contrarotating UDF engine rotor configurations were studied in an anechoic facility with a 1/5-scale rotor model. Tests were conducted at simulated takeoff and cutback conditions to determine the effects of such configurational variations as front and back blade row blade-numbers, tip speeds, and rotor-to-rotor spacings. Significant overall acoustic improvements result with increasing blade numbers. Steady-loading noise, as represented by noise levels at the blade passing frequencies, decreased with reduced tip speed for a given thrust. Standard-diameter and clipped-diameter aft fan blade effects were also tested. O.C.

A89-34139
SOME ASPECTS OF THE NUMERICAL MODELING OF THE NONSTATIONARY HEAT CONDUCTIVITY OF GAS TURBINE COMPONENTS [NEKOTORYE VOPROSY CHISLENNOGO MODELIROVANIIA NESTATSIONARNOI TEPLOPROVODNOSTI DETALEI GAZOVYKH TURBIN]
V. G. KADYSHEV and V. A. STRUNKIN Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 55-59. In Russian. refs

Some problems associated with the implementation of the finite element method in calculations of the thermal state of gas turbine components are discussed. In particular, methods are described which make it possible to reduce the computational effort by a factor of 4-5. This is achieved by using a modified numerical scheme and through an optimum combination of the integration step and of the upper relaxation parameter in solving systems of algebraic equations. V.L.

A89-34140
EFFECT OF THE DESIGN OF A TWO-ROW NOZZLE RING ON THE EFFICIENCY OF A TURBINE STAGE OF MEDIUM ROTOR SOLIDITY [VLIIANIE KONSTRUKTSII DVUKHRIADNOGO SOPLOVOGO APPARATA NA EFFEKTIVNOST' TURBINNOI STUPENI SREDNEI VEERNOSTI]
IU. L. KORZUNOV, S. S. KOSTIUCHENKO, IU. I. MITIUSHKIN, V. D. RONZIN, and V. M. CHERNYSH Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 59-64. In Russian. refs

A study is made of the effect of the tangential tilt of back-twisted blades and of the profiling of the outer boundary surface of a two-row nozzle ring on the efficiency of a medium-solidity turbine cascade. It is shown that the two-row nozzle ring design proposed here reduces the thrust ratio gradient over the blade height and increases the efficiency of the turbine stage. The increase in turbine efficiency resulting from the substitution of a two-row nozzle ring for a single-row ring is estimated at 0.8 percent. V.L.

A89-34141
AN ANALYTICAL-EXPERIMENTAL STUDY OF RING GAP LOSSES IN SMALL AXIAL-FLOW TURBINES [RASCHETNO-EKSPERIMENTAL'NOE ISSLEDOVANIE POTER' OT RADIAL'NOGO ZAZORA V OSEVYKH MALORAZMERNYKH TURBINAKH]
B. A. KRYLOV and S. A. GUSAROV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 64-68. In Russian. refs

Ring gap losses in small axial-flow turbines are investigated analytically and experimentally using advanced experimental design methods. A generalized expression is obtained which provides a way to accurately account for the effect of ring gap losses in this class of turbines. It is shown that ring gap losses have a noticeable effect on turbine efficiency. V.L.

A89-34150
NOISE LEVELS OF A COMBINED BYPASS-PROPFAN ENGINE IN THE FAR SONIC FIELD [UROVNI SHUMA DVIGATELIA KOMBINIROVANNOI SKHEMY TRDD-TVVD V DAL'NEM ZVUKOVOM POLE]
I. S. ZAGUZOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 91, 92. In Russian.

The acoustic characteristics of a combined bypass-propfan engine with counterrotating coaxial propellers are investigated analytically in the far sonic field. Calculations are carried out for standard propellers with straight blades. Noise matrices of the principal sources are obtained for different operating regimes and then used for estimating environmental noise levels produced by aircraft equipped by such engines. Possible ways of reducing the engine noise level are briefly discussed. V.L.

A89-34409#
A NEW METHOD FOR THE THERMODYNAMIC CALCULATION OF COMBUSTION CHAMBERS
TIANYU ZHU (Air Force PR China, Aeronautic Repair Research Institute, People's Republic of China) and FUQUN CHEN (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Propulsion Technology (ISSN 1001-4055), Feb. 1989, p. 27-30, 73. In Chinese, with abstract in English.

For the thermodynamic calculation of the gas turbine combustion chamber, there are two methods to be selected, the noniterative precise method (NIPM) and the isothermal enthalpy difference method (IEDM). According to the principle of NIPM, a general solution of the energy equilibrium equation for the main combustion chamber, the reheat combustor, and the exhaust-fired burners in the gas turbine and steam turbine combined cycle, using gas or liquid fuel, is developed in this paper. It is shown that IEDM is the linear approximation of NIPM, and the fuel-air ratio calculated by the former is slightly less than that by the latter, but their relative difference will not exceed 0.5 percent. The general solution provided in this paper can also be applied to the thermodynamic calculation of all kinds of engine combustion chamber using gas or liquid fuel in aerospace. Author

N89-20131 Cornell Univ., Ithaca, NY.
AN ANALYTICAL AND NUMERICAL STUDY OF AXIAL FLOW COMPRESSOR INSTABILITY Ph.D. Thesis
FRANCES ELIZABETH MCCAUGHAN 1988 192 p
Avail: Univ. Microfilms Order No. DA8821176

An axial-flow compressor is an important component of the turbo-jet engine. It is of great interest to characterize the possible modes of response of this system with respect to variations in the values of the governing parameters. A mathematical model of an idealized axial-flow compression system was developed by Moore and Greitzer. The properties of this model, which consists of a set of partial differential equations, were investigated by both analytical and numerical means. A single-harmonic truncation of the full model was investigated by means of modern dynamical systems theory. A thorough investigation is made of the stability of the equilibria and periodic solutions, revealing period-doubling bifurcations which lead to apparently chaotic behavior. Using Cornell's supercomputing facilities, an extensive study of the full set of partial differential equations using a pseudo-spectral numerical scheme was also performed. The effects of the parameters on the rotating stall performance are investigated. The effects of inlet guide vane loss on rotating stall performance were also discussed. An evaluation is made of the h prime = -g approximation, and a spectral analysis of the rotating stall cell determined from the full model suggests why this breaks down. Dissert. Abstr.

N89-20132*# Pratt and Whitney Aircraft, East Hartford, CT. Commercial Engineering Dept.
STRUCTURAL TAILORING OF ADVANCED TURBOPROPS (STAT) PROGRAMMER'S MANUAL
K. W. BROWN and P. R. HARVEY Mar. 1989 53 p
(Contract NAS3-23941)
(NASA-CR-182164; NAS 1.26:182164; PWA-5967-51) Avail: NTIS HC A04/MF A01 CSCL 21E

The Structural Tailoring of Advanced Turboprops (STAT) computer program was developed to perform numerical optimizations on highly swept propfan blades. This manual describes the functionality of the STAT system from a programmer's viewpoint. It provides a top-down description of module intent and interaction. The purpose of this manual is to familiarize the programmer with the STAT system should he/she wish to enhance or verify the program's function. Author

N89-20133*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL INVESTIGATION OF TRANSONIC OSCILLATING CASCADE AERODYNAMICS
DANIEL H. BUFFUM and SANFORD FLEETER (Purdue Univ., West Lafayette, IN.) Jan. 1989 15 p Presented at the 27th Aerospace Sciences Meeting, Reno, NV, 9-12 Jan. 1989; sponsored in part by AIAA Previously announced in IAA as A89-26369
(Contract NAG3-656)
(NASA-TM-101993; E-4697; NAS 1.15:101993) Avail: NTIS HC A03/MF A01 CSCL 21E

Fundamental experiments are performed in the NASA Lewis Transonic Oscillating Cascade Facility to investigate the subsonic and transonic aerodynamics of cascaded airfoils executing torsion mode oscillations at realistic values of reduced frequency. In particular, an unsteady aerodynamic influence coefficient technique is developed and utilized. In this technique, only one airfoil in the cascade is oscillated at a time, with the resulting airfoil surface unsteady pressure distribution measured on one dynamically instrumented reference airfoil. The unsteady aerodynamics of an equivalent cascade with all airfoils oscillating at any specified interblade phase angle are then determined through a vector summation of these data. These influence coefficient determined oscillating cascade data were correlated with: (1) data obtained in this cascade with all airfoils oscillating at several interblade phase angle values; and (2) predictions from a classical linearized unsteady cascade model. Author

N89-20134*# Cornell Univ., Ithaca, NY.
PROPULSION OVER A WIDE MACH NUMBER RANGE Final Report M.S. Thesis
EDWIN L. RESLER, JR. and BARRY M. GREENBERG Mar. 1989 71 p
(Contract NAG3-803)
(NASA-CR-182267; NAS 1.26:182267) Avail: NTIS HC A04/MF A01 CSCL 21E

Criteria is presented to assess the relative merits of different propulsion systems. Previous references focus mainly on subsonic or low supersonic flight speeds. The main focus here is on a higher range, from low supersonic to orbital velocities. Air breathing propulsion systems for hypersonic flight persent the engine designer with circumstances that differ in important fundamental ways from those encountered in engines designed for operation at subsonic or low supersonic speeds. This analysis highlights the importance of various features of hypersonic engine design. Since the performance of hypersonic engines are energy limited, unlike low speed engines which are stagnation pressure limited, the efficient use of the energy of the fuel used is critical to minimize the

take-off fuel mass fraction of the vehicle. Furthermore, since the required energy increase of a vehicle per incremental speed change increases with speed, the engine must be designed to operate efficiently at high speed. An analysis of engine performance in terms of entropy changes of the flow passing through the engine allows comparison of various engine designs as well as a convenient method to determine the effect of individual engine component efficiencies on overall engine performance. Author

N89-20135*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TOWARD IMPROVED DURABILITY IN ADVANCED AIRCRAFT ENGINE HOT SECTIONS
DANIEL E. SOKOLOWSKI, ed. Washington Apr. 1989 121 p Proceedings of the 33rd ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, 5-9 Jun. 1988 Previously announced in IAA as A88-54137
(NASA-TM-4087; E-4468; NAS 1.15:4087) Avail: NTIS HC A06/MF A01 CSCL 21E

The conference on durability improvement methods for advanced aircraft gas turbine hot-section components discussed NASA's Hot Section Technology (HOST) project, advanced high-temperature instrumentation for hot-section research, the development and application of combustor aerothermal models, and the evaluation of a data base and numerical model for turbine heat transfer. Also discussed are structural analysis methods for gas turbine hot section components, fatigue life-prediction modeling for turbine hot section materials, and the service life modeling of thermal barrier coatings for aircraft gas turbine engines.

N89-20136*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NASA HOST PROJECT OVERVIEW
DANIEL E. SOKOLOWSKI *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 1-4 Apr. 1989 Previously announced in IAA as A88-54138
Avail: NTIS HC A06/MF A01 CSCL 21E

NASA's Hot Section Technology (HOST) program has developed improved analytical models for the aerothermal environment, thermomechanical loading, material behavior, structural response, and service life of aircraft gas turbine engines' hot section components. These models, in conjunction with sophisticated computer codes, can be used in design analyses of critical combustor and turbine elements. Toward these ends, efforts were undertaken in instrumentation, combustion, turbine heat transfer, structural analysis, fatigue-fracture, and surface protection. Attention is presently given to the organization of HOST activities and their specific subject matter. Author

N89-20137*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED HIGH TEMPERATURE INSTRUMENT FOR HOT SECTION RESEARCH APPLICATIONS
D. R. ENGLUND and R. G. SEASHOLTZ *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 5-21 Apr. 1989 Previously announced in IAA as A88-54139
Avail: NTIS HC A06/MF A01 CSCL 21E

Programs to develop research instrumentation for use in turbine engine hot sections are described. These programs were initiated to provide improved measurements capability as support for a multidisciplinary effort to establish technology leading to improved hot section durability. Specific measurement systems described here include heat flux sensors, a dynamic gas temperature measuring system, laser anemometry for hot section applications, an optical system for viewing the interior of a combustor during operation, thin film sensors for surface temperature and strain measurements, and high temperature strain measuring systems. The state of development of these sensors and measuring systems is described, and, in some cases, examples of measurements made with these instruments are shown. Work done at the NASA Lewis Research Center and at various contract and grant facilities is covered. Author

N89-20138*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ASSESSMENT, DEVELOPMENT, AND APPLICATION OF COMBUSTOR AEROTHERMAL MODELS
J. D. HOLDEMAN, H. C. MONGIA, and E. J. MULARZ (Army Aviation Systems Command, Cleveland, OH.) *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 23-37 Apr. 1989 Previously announced in IAA as A88-54140
Avail: NTIS HC A06/MF A01 CSCL 21E

The gas turbine combustion system design and development effort is an engineering exercise to obtain an acceptable solution to the conflicting design trade-offs between combustion efficiency, gaseous emissions, smoke, ignition, restart, lean blowout, burner exit temperature quality, structural durability, and life cycle cost. For many years, these combustor design trade-offs have been carried out with the help of fundamental reasoning and extensive component and bench testing, backed by empirical and experience correlations. Recent advances in the capability of computational fluid dynamics codes have led to their application to complex 3-D flows such as those in the gas turbine combustor. A number of U.S. Government and industry sponsored programs have made significant contributions to the formulation, development, and verification of an analytical combustor design methodology which will better define the aerothermal loads in a combustor, and be a valuable tool for design of future combustion systems. The contributions made by NASA Hot Section Technology (HOST) sponsored Aerothermal Modeling and supporting programs are described. Author

N89-20139*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
REVIEW AND ASSESSMENT OF THE DATABASE AND NUMERICAL MODELING FOR TURBINE HEAT TRANSFER
H. J. GLADDEN and R. J. SIMONEAU *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 39-55 Apr. 1989 Previously announced in IAA as A88-54141
Avail: NTIS HC A06/MF A01 CSCL 21E

The objectives of the NASA Hot Section Technology (HOST) Turbine Heat Transfer subproject were to obtain a better understanding of the physics of the aerothermodynamic phenomena and to assess and improve the analytical methods used to predict the flow and heat transfer in high-temperature gas turbines. At the time the HOST project was initiated, an across-the-board improvement in turbine design technology was needed. A building-block approach was utilized and the research ranged from the study of fundamental phenomena and modeling to experiments in simulated real engine environments. Experimental research accounted for approximately 75 percent of the funding while the analytical efforts were approximately 25 percent. A healthy government/industry/university partnership, with industry providing almost half of the research, was created to advance the turbine heat transfer design technology base. Author

N89-20140*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
STRUCTURAL ANALYSIS METHODS DEVELOPMENT FOR TURBINE HOT SECTION COMPONENTS
R. L. THOMPSON *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 57-82 Apr. 1989 Previously announced in IAA as A88-54142
Avail: NTIS HC A06/MF A01 CSCL 21E

The structural analysis technologies and activities of the NASA Lewis Research Center's gas turbine engine HOT Section Technoloogy (HOST) Program are summarized. The technologies synergistically developed and validated include: time-varying thermal/mechanical load models; component-specific automated geometric modeling and solution strategy capabilities; advanced inelastic analysis methods; inelastic constitutive models; high-temperature experimental techniques and experiments; and nonlinear structural analysis codes. Features of the program that incorporate the new technologies and their application to hot section component analysis and design are described. Improved

and, in some cases, first-time 3-D nonlinear structural analyses of hot section components of isotropic and anisotropic nickel-base superalloys are presented. Author

N89-20141*# General Electric Co., Cincinnati, OH.
STRUCTURAL ANALYSIS APPLICATIONS
R. L. MCKNIGHT *In* NASA, Lewis Research Center, Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 83-95 Apr. 1989 Previously announced in IAA as A88-54143
Avail: NTIS HC A06/MF A01 CSCL 21E

An account is given of the application of computer codes for the efficient conduct of three-dimensional inelastic analyses to aircraft gas turbine combustor, turbine blade, and turbine stator vane components. The synergetic consequences of the program's activities are illustrated by an evaluation of the computer analyses of thermal barrier coatings and of the Space Shuttle Main Engine's High Pressure Fuel Turbopump turbine blading. This software, in conjunction with state-of-the-art supercomputers, can significantly reduce design-task burdens. Author

N89-20142*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FATIGUE LIFE PREDICTION MODELING FOR TURBINE HOT SECTION MATERIALS
G. R. HALFORD, T. G. MEYER, R. S. NELSON, D. M. NISSLEY, and G. A. SWANSON *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 97-107 Apr. 1989 Previously announced in IAA as A88-54144 Prepared in cooperation with Pratt and Whitney Aircraft, East Hartford, CT
Avail: NTIS HC A06/MF A01 CSCL 21E

A major objective of the fatigue and fracture efforts under the NASA Hot Section Technology (HOST) program was to significantly improve the analytic life prediction tools used by the aeronautical gas turbine engine industry. This was achieved in the areas of high-temperature thermal and mechanical fatigue of bare and coated high-temperature superalloys. The cyclic crack initiation and propagation resistance of nominally isotropic polycrystalline and highly anisotropic single crystal alloys were addressed. Life prediction modeling efforts were devoted to creep-fatigue interaction, oxidation, coatings interactions, multiaxiality of stress-strain states, mean stress effects, cumulative damage, and thermomechanical fatigue. The fatigue crack initiation life models developed to date include the Cyclic Damage Accumulation (CDA) and the Total Strain Version of Strainrange Partitioning (TS-SRP) for nominally isotropic materials, and the Tensile Hysteretic Energy Model for anisotropic superalloys. A fatigue model is being developed based upon the concepts of Path-Independent Integrals (PII) for describing cyclic crack growth under complex nonlinear response at the crack tip due to thermomechanical loading conditions. A micromechanistic oxidation crack extension model was derived. The models are described and discussed. Author

N89-20143*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LIFE MODELING OF THERMAL BARRIER COATINGS FOR AIRCRAFT GAS TURBINE ENGINES
R. A. MILLER *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 109-115 Apr. 1989 Previously announced in IAA as A88-54145
Avail: NTIS HC A06/MF A01 CSCL 21E

Thermal barrier coating life models developed under the NASA Lewis Research Center's Hot Section Technology (HOST) Program are summarized. An initial laboratory model and three design-capable models are discussed. Current understanding of coating failure mechanisms are also summarized. The materials and structural aspects of thermal barrier coatings have been successfully integrated under the HOST program to produce models which may now or in the near future be used in design. Efforts on this program continue at Pratt and Whitney Aircraft where their model is being extended to the life prediction of physical vapor deposited thermal barrier coatings. Author

N89-20144*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
VIEWS ON THE IMPACT OF HOST
J. B. ESGAR (Sverdrup Technology, Inc., Cleveland, OH.) and DANIEL E. SOKOLOWSKI *In its* Toward Improved Durability in Advanced Aircraft Engine Hot Sections p 117-123 Apr. 1989 Previously announced in IAA as A88-54146
Avail: NTIS HC A06/MF A01 CSCL 21E

The Hot Section Technology (HOST) Project, which was initiated by NASA Lewis Research Center in 1980 and concluded in 1987, was aimed at improving advanced aircraft engine hot section durability through better technical understanding and more accurate design analysis capability. The project was a multidisciplinary, multiorganizational, focused research effort that involved 21 organizations and 70 research and technology activities and generated approximately 250 research reports. No major hardware was developed. To evaluate whether HOST had a significant impact on the overall aircraft engine industry in the development of new engines, interviews were conducted with 41 participants in the project to obtain their views. The summarized results of these interviews are presented. Emphasis is placed on results relative to three-dimensional inelastic structural analysis, thermomechanical fatigue testing, constitutive modeling, combustor aerothermal modeling, turbine heat transfer, protective coatings, computer codes, improved engine design capability, reduced engine development costs, and the impacts on technology transfer and the industry-government partnership. Author

N89-20145# Army Aviation Engineering Flight Activity, Edwards AFB, CA.
AIRWORTHINESS AND FLIGHT CHARACTERISTICS EVALUATION OF AN IMPROVED ENGINE AIR FILTRATION SYSTEM ON THE UH-1H HELICOPTER Final Report, 16 Sep. 1987 - 29 Mar. 1988
JAMES D. BROWN, JOHN S. LAWRENCE, PAUL W. LOSIER, CHARLES E. CASSIL, and MATTHEW S. GRAHAM May 1988 160 p
(AD-A203446; USAAEFA-86-16) Avail: NTIS HC A08/MF A01 CSCL 21E

The U.S. Army Aviation Engineering Flight Activity conducted an Airworthiness and Flight Characteristics evaluation of the UH-1H aircraft with an Improved Engine Air Filtration System (IEAFS) installed and with the standard filter installed between 16 September 1987 and 29 February 1988. Aircraft performance and handling qualities, engine-air induction system compatibility, and engine performance with the IEAFS installed were evaluated. This evaluation was conducted at Edwards AFB, California. Twenty-five flights were conducted for a total of 20.1 productive flight hours. The aircraft performance and handling qualities, engine vibrations, and inlet temperature characteristics with the IEAFS installed are not significantly different from those of the standard UH-1H. The inlet pressure distortion and engine installation losses with the IEAFS installed are less than those of the standard UH-1H. One deficiency, the poor reliability of the IEAFS latch rivets, was identified. One shortcoming, the poor reliability of the latch lever locking device, was identified. Both the deficiency and the shortcoming should be corrected before production. GRA

N89-20146*# Oklahoma Univ., Norman. School of Aerospace and Mechanical Engineering.
A FIRST SCRAMJET STUDY
GEORGE EMANUEL Apr. 1989 55 p
(Contract NAG1-886)
(NASA-CR-184965; NAS 1.26:184965) Avail: NTIS HC A04/MF A01 CSCL 21E

A variety of related scramjet engine topics are examined. The flow is assumed to be 1-D, the gas is thermally and calorically perfect, and focus is on low hypersonic Mach numbers. The thrust and lift of an exposed half nozzle, which is used on the aerospace plane, is evaluated as well as a fully confined nozzle. A rough estimate of the drag of an aerospace plane is provided. Thermal effects and shock waves are next discussed. A parametric scramjet model is then presented based on the influence coefficient method,

which evaluates the dominant scramjet processes. The independent parameters are the ratio of specific heats, a nondimensional heat addition parameter, and four Mach numbers. The total thrust generated by the combustor and nozzle is shown to be independent of the heat release distribution and the combustor exit Mach number, providing thermal choking is avoided. An operating condition for the combustor is found that maximizes the thrust. An alternative condition is explored when this optimum is no longer realistic. This condition provides a favorable pressure gradient and a reasonable area ratio for the combustor. Parametric results based on the model is provided. Author

N89-20943*# McDonnell Aircraft Co., Saint Louis, MO. Computation Fluid Dynamics.
TRANSONIC PROPULSION SYSTEM INTEGRATION ANALYSIS AT MCDONNELL AIRCRAFT COMPANY
RAYMOND R. COSNER *In* NASA, Langley Research Center, Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 409-436 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 21E

The technology of Computational Fluid Dynamics (CFD) is becoming an important tool in the development of aircraft propulsion systems. Two of the most valuable features of CFD are: (1) quick acquisition of flow field data; and (2) complete description of flow fields, allowing detailed investigation of interactions. Current analysis methods complement wind tunnel testing in several ways. Herein, the discussion is focused on CFD methods. However, aircraft design studies need data from both CFD and wind tunnel testing. Each approach complements the other. Author

N89-20995*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A REAL-TIME SIMULATOR OF A TURBOFAN ENGINE
JONATHAN S. LITT (Army Aviation Research and Development Command, Cleveland, OH.), JOHN C. DELAAT, and WALTER C. MERRILL Mar. 1989 32 p
(NASA-TM-100869; E-4578; NAS 1.15:100869; AVSCOM-TR-89-C-001) Avail: NTIS HC A03/MF A01 CSCL 21E

A real-time digital simulator of a Pratt and Whitney F100 engine has been developed for real-time code verification and for actuator diagnosis during full-scale engine testing. This self-contained unit can operate in an open-loop stand-alone mode or as part of closed-loop control system. It can also be used for control system design and development. Tests conducted in conjunction with the NASA Advanced Detection, Isolation, and Accommodation program show that the simulator is a valuable tool for real-time code verification and as a real-time actuator simulator for actuator fault diagnosis. Although currently a small perturbation model, advances in microprocessor hardware should allow the simulator to evolve into a real-time, full-envelope, full engine simulation. Author

N89-20996*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPENDIUM OF CONTROLLED DIFFUSION BLADES GENERATED BY AN AUTOMATED INVERSE DESIGN PROCEDURE
JOSE M. SANZ Mar. 1989 204 p
(NASA-TM-101968; E-4665; NAS 1.15:101968) Avail: NTIS HC A10/MF A01 CSCL 21E

A set of sample cases was produced to test an automated design procedure developed at the NASA Lewis Research Center for the design of controlled diffusion blades. The range of application of the automated design procedure is documented. The results presented include characteristic compressor and turbine blade sections produced with the automated design code as well as various other airfoils produced with the base design method prior to the incorporation of the automated procedure. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

A89-32725* Rice Univ., Houston, TX.
ABORT LANDING GUIDANCE TRAJECTORIES IN THE PRESENCE OF WINDSHEAR
A. MIELE, T. WANG, C. Y. TZENG (Rice University, Houston, TX), and W. W. MELVIN (Air Line Pilots Association, Washington, DC) Franklin Institute, Journal (ISSN 0016-0032), vol. 326, no. 2, 1989, p. 185-220. Research supported by Boeing Commercial Airplane Co. and Air Line Pilots Association. refs
(Contract NAG1-516)

The flight trajectory of abort landing in the presence of windshear is examined with reference to flight in a vertical plane. It is assumed that the only control is the angle of attack. Inequality constraints are imposed on both the angle of attack and its time derivative. Numerical results are obtained for several combinations of windshear intensities and initial altitudes. Guidance trajectories are considered, approximating the optimal trajectories and using local information on the state of the aircraft, the initial altitude, and the total wind velocity difference. Results are presented for optimal trajectories, guidance trajectories, simplified guidance trajectories, constant pitch trajectories, and maximum angle of attack trajectories. R.B.

A89-33563
DEVELOPMENT AND IMPLEMENTATION OF FLIGHT CONTROL SYSTEM FOR A RESEARCH DROP MODEL
M. A. NASEEM (British Aerospace, PLC, Military Aircraft Div., Brough, England) and A. JEAN ROSS (Royal Aerospace Establishment, Farnborough, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 14.1-14.14. Research supported by the Ministry of Defence Procurement Executive. refs

An account is given of the design, implementation, and testing of the flight control systems employed by two, slightly different High Incidence Research Model (HIRM) unmanned vehicle configurations used in free-flight tests of aircraft control methods at angles-of-attack up to, and beyond, departure. These configurations are both of tailless, canard/delta lifting surface type. Flight record samples are presented to illustrate the successes achieved and the difficulties encountered. Although the two HIRM vehicles are not RPVs, much that was learned during their flight testing is applicable to RPV control system design. O.C.

A89-33566
THE COMPUTER CONTROLLED SYSTEM FOR MULTI-DRONE PERFORMING FORMATION FLIGHT IN A SAME AERIAL ZONE
BAIRONG YU (Yu He Machinery Factory, Nanjing, People's Republic of China) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 18.1-18.9. refs

A microcomputer-controlled FM radio remote-control system has been designed to accomplish multiple RPV piloting tasks within a given aerial zone. Attention is given to the performance criteria to which the communication encoder and control software have been designed to ensure system stability, reliability, and resistance to interference. The principal use of this remote control system is in the collective, formation-flying control of target drones. Block diagrams are presented for the various hardware and software components of the system. O.C.

A89-34130
A MATHEMATICAL MODEL OF AIRCRAFT SPIN AND RESULTS OF ITS COMPUTER INTEGRATION [MATEMATICHESKAIA MODEL' SHTOPORA SAMOLETA I

REZUL'TATY INTEGRIROVANIIA EE NA EVM]
V. F. NATUSHKIN Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 18-22. In Russian.

Aircraft spin dynamics is examined on the basis of a new mathematical model which treats the spin as a complex phenomenon accompanied by a strong manifestation of inertial, aerodynamic, kinematic, and gyroscopic cross constraints. Criteria determining conditions for the onset and cessation of the spinning motion are obtained, as are optimal spin control laws. The predictions of the model proposed here are found to be in good agreement with experimental data. V.L.

A89-34897*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AEROELASTIC DEFORMATION EFFECTS ON THE STOPPED-ROTOR DYNAMICS OF AN X-WING AIRCRAFT
MICHAEL G. GILBERT (NASA, Langley Research Center, Hampton, VA) and WALTER A. SILVA (Planning Research Corp., Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 482-488. Previously cited in issue 22, p. 3538, Accession no. A87-49613. refs

A89-35045*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACTIVE CONTROL LAW SYNTHESIS FOR FLEXIBLE AIRCRAFT
V. MUKHOPADHYAY (NASA, Langley Research Center; PRC Kentron, Inc., Hampton, VA) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 183-188. refs
(Contract NAS1-18000)

An application of an active control law synthesis procedure is presented, to meet multiple design requirements for a flexible aircraft modeled by a large order state space system. In this synthesis procedure, a linear quadratic Gaussian type cost function is minimized by updating the free parameters of the control law, while satisfying a set of constraints on the design loads, responses and stability margins. Analytical expressions for gradients of the cost function and the constraints, with respect to the control law design variables are used to facilitate rapid numerical convergence. These gradients can also be used for sensitivity study. A stable classical control law as well as an estimator-based full or reduced order control law can be modified, in order to meet individual root-mean-square response limitations as well as minimum singular value restrictions. Both analog and digital control laws can be optimized. Low order, robust control laws were synthesized for flutter suppression of a flexible aircraft. Author

A89-35286
VARIABLE STRUCTURE CONTROL LAWS FOR AIRCRAFT MANOEUVRES
S. K. MUDGE and R. J. PATTON (York, University, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 564-568. refs

The design procedure for a variable structure control system (VSCS) for aircraft maneuvers is formulated, and the technique is illustrated using a pitch-pointing/vertical translation maneuver developed for a combat aircraft by Sobel and Shapiro (1985) and Andry et al. (1983). The performance of the VSCS controller is assessed using a fully nonlinear simulation which incorporates wind turbulence in the form of a Dryden spectrum. The performance of the VSCS is compared with that of the purely linear control used to define the model dynamics. I.S.

A89-35297
DESIGN OF ROBUST MULTIVARIABLE HELICOPTER CONTROL LAWS FOR HANDLING QUALITIES ENHANCEMENT
A. YUE (Oxford University, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 689-694. Research supported by SERC. refs

Control laws for hover flight conditions of a typical battlefield helicopter are developed. The loop shaping procedure for designing the control laws using H-infinity optimization is presented. The procedure is analyzed with respect to the singular values of the sensitivity and complementary sensitivity functions, using a nominal model of the helicopter trimmed about the hover. Results of nonlinear time simulations demonstrated that the design was robustly stable to the unmodeled rotor and actuator dynamics and to the unmodeled dynamics due to changes in the flight envelope. I.S.

A89-35300
VARIABLE STRUCTURE MODEL-FOLLOWING CONTROL OF FLIGHT DYNAMICS
A. S. I. ZINOBER, M. K. YEW (Sheffield, University, England), and R. J. PATTON (York, University, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 707-712. refs
(Contract SERC-GR/D/55436)

This paper discusses the design of a control system which would force the aircraft dynamics to follow the dynamics of an ideal problem. The model-following problem is considered using the variable structure control approach of Young (1978) and Zinober (1984) and a CAD design package VASSYD with a robust eigenstructure algorithm; the objective of the control design is to force the error between the model and the plant to zero as time tends to infinity. The simulation results, obtained for flight conditions different from the nominal model on which the control design was based, indicated clearly that the plant response follows the model trajectory, and the error between the two responses is rapidly eliminated. I.S.

A89-35301
MULTIVARIABLE DESIGN OF A BANK-TO-TURN AUTOPILOT FOR COMMAND GUIDANCE
G. MCCONNELL (Short Brothers, PLC, London, England) and G. W. IRWIN (Belfast, Queen's University, Northern Ireland) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 713-718. refs

This paper describes a design of a bank-to-turn autopilot for command guidance. A multivariable approach was used, which assumes that the roll rate is a constant at each design point and determines a steady-state control law for this fixed value. The full autopilot controller is then implemented by scheduling the resulting steady-state controllers. The results demonstrate an improvement in performance by the gain scheduled controllers. Two multivariable design methodologies, namely, the frequency domain characteristics locus method and the time domain linear quadratic optimal control method, are described. I.S.

A89-35302
IMPLEMENTATION OF A TRANSPUTER-BASED FLIGHT CONTROLLER
P. J. FLEMING, D. F. GARCIA NOCETTI, and H. A. THOMPSON (North Wales, University College, Bangor, Wales) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 719-724. Research supported by the Royal Aircraft Establishment.

This paper describes the software and hardware aspects of a pilot study carried out with the goal of mapping an existing aircraft flight control law for the Versatile Autopilot (VAP) onto a parallel processing system. The potential of the INMOS transputer and its associated programming language OCCAM for the implementation of this control law was investigated. The paper describes methods used to generate the concurrent realization of the height-hold mode, the most complex mode operated by the VAP control law, using two alternative approaches, parallel branches and heuristic. The

adaptability and extendability of both approaches, as well as the execution speed and the ease of programming, are evaluated.
I.S.

N89-20147 Virginia Polytechnic Inst. and State Univ., Blacksburg.
ROBUST STABILIZATION OF LINEAR TIME-INVARIANT UNCERTAIN SYSTEMS VIA LYAPUNOV THEORY Ph.D. Thesis
CHIEN-HSIANG CHAO 1988 114 p
Avail: Univ. Microfilms Order No. DA8817401

The problem of synthesizing a robust stabilizing feedback controller for linear time-invariant systems with constant uncertainties that are not required to satisfy matching conditions is considered. Only the bounds on the uncertainties are required and no statistical property of the uncertainties is assumed. The systems under consideration are described by linear state equations with uncertainties. Lyapunov theory is exploited to establish the conditions for stabilizability of the closed loop system. Linear controller design is also investigated. Under the same assumptions for the existence of a stabilizing discontinuous controller, it is shown that a linear robust stabilizing controller always exists. Three examples are included to illustrate the design procedures for robust controllers. Dissert. Abstr.

N89-20148 Purdue Univ., West Lafayette, IN.
MODAL COST ANALYSIS OF FLEXIBLE STRUCTURES: MODELING FLEXIBLE STRUCTURES FOR CONTROL DESIGN Ph.D. Thesis
ANREN HU 1987 200 p
Avail: Univ. Microfilms Order No. DA8814487

The integration issues of structural modeling and control design for large flexible structures are very important for developing sound models in a closed loop environment. Consideration of these issues leads one to conclude that the modeling problem and control problem are not independent. The connection between these two problems must be understood to develop reliable control algorithms and reduce the cost of extensive laboratory and flight testing. It is this input-output type phenomenon which must be reflected in structural modeling. The modal costs represent the contribution of a vibration mode in the system response for given input and output locations. A complete modal cost analysis is provided for certain distributed parameter systems and shows that structural modeling and model reduction methods should be influenced by the specific control objectives. The analysis proceeds via the following steps: Convergence properties of modal costs are discussed for vibration of various simple continua. Open loop model cost analysis is applied to finite element models of beam-like structures. Finite element models are used to develop Linear Quadratic Gaussian control laws while exact models are used to evaluate performance of the resulting closed loop systems. A comprehensive modal cost analysis is presented for simple continua and discusses its implications in subsequent control system design. Dissert. Abstr.

N89-20149 California Univ., Los Angeles.
ACTIVE CONTROL HELICOPTER AEROMECHANICAL AND AEROELASTIC INSTABILITIES Ph.D. Thesis
MARC D. TAKAHASHI 1988 367 p
Avail: Univ. Microfilms Order No. DA8822168

The active control of three helicopter rotor instabilities is investigated using a coupled rotor/fuselage helicopter analysis. The mathematical model is derived to capture air resonance and includes important features such as blade torsional flexibility, unsteady aerodynamics, and forward flight, which are effects that were ignored in the few previous studies on air resonance control. Because of these modeling features, two other aeroelastic instabilities can also be simulated with the model and a brief investigation into the active control of these instabilities is made. The first of these is a flap-lag-torsion instability inforward flight and the second is a flap-lag instability that is induced by the presence of the fuselage degrees of freedom. A realistic helicopter configuration experiencing an air resonance instability is then selected and it is used in two active control studies. In the first study, open loop damping data is presented and the effect of blade torsional flexibility, unsteady aero-dynamics, forward flight, periodic terms, and trim solution is shown. The model is then used with linear optimal control theory to investigate the influence of these effects on the closed loop damping. In the second study, the feasibility of designing simple implemetable controllers to suppress air resonance throughout a wide range of operating conditions is demonstrated. The control design method is also applied to a different configuration experiencing a fuselage induced flap-lag instability. Dissert. Abstr.

N89-20150 Massachusetts Inst. of Tech., Cambridge.
ON-BOARD AUTOMATIC AID AND ADVISORY FOR PILOTS OF CONTROL-IMPAIRED AIRCRAFT Ph.D. Thesis
ELAINE ANN WAGNER 1988 261 p
Avail: Univ. Microfilms Order No. DA8821885

The consideration of the problem of aircraft control failures from a broader, more meaningful viewpoint than with control loop reconfiguration or redesign is presented. The additional considerations involved in making full recoveries from control failures are first categorized. Performance and operating constraints that are best taken into account explicitly are presented, and there is a discussion of the sometimes very important role of explicit post-failure retrim of the aircraft. Because it can be expected that pilots, if unaided, may continue often to be unable to recover aircraft after control failure, these considerations were cast in the form of knowledge and capabilities that an automatic aid and pilot advisory system should have. Because automatic emergency control is seen to be a very significant part of the proposed system, a rule-based expert-type system to find a successful control strategy was developed for elevator failures on the C-130. This system directs pre-simulation of the control strategy, changing it on the basis of empirical guidelines concerning simple, objective features of the aircraft response to the strategy. The advisory function of the recovery-aiding system is also described. The issues of pilot interface are discussed, as well as what to calculate to support the advisory during various flight phases. Dissert. Abstr.

N89-20998 Purdue Univ., West Lafayette, IN.
ACTUATION CONSTRAINTS IN MULTIVARIABLE FLIGHT CONTROL SYSTEMS Ph.D. Thesis
MARK RONALD ANDERSON 1988 202 p
Avail: Univ. Microfilm Oder No. DA8825502

This research deals with stability and performance robustness of non-linear multivariable feedback control systems. The systems considered include linear as well as non-linear idealizations, where non-linear models are used to represent practical limitations (limiting) in the physical devices. A robustness analysis methodology, intended for use early in the control-law synthesis, is developed to evaluate stability and performance with respect to control surface deflection and rate limits specifically. The methodology consists of three steps. First, a linear actuator signal approximation is chosen based on a priori bounds, developed herein, between the time response of the linear signal approximation and the actual actuator signal. Second, the peak magnitude of the linear signal approximation is used to define a quasi-linear representation of the deflection and rate limit saturation elements using either describing function or sector methods. Third, stability and performance robustness with respect to the quasi-linear saturation models may then be evaluated using matrix-singular-value or eigenvalue techniques. The analysis methodology is used to evaluate the stability robustness of two high-authority, multivariable flight control laws for two different pilot stick force inputs to a generic foward-swept-wing aircraft.
Dissert. Abstr.

N89-20999*# Systems Technology, Inc., Hawthorne, CA.
TAILLESS AIRCRAFT PERFORMANCE IMPROVEMENTS WITH RELAXED STATIC STABILITY
IRVING L. ASHKENAS and DAVID H. KLYDE Mar. 1989 145 p
(Contract NAS1-18524)
(NASA-CR-181806; NAS 1.26:181806; STI-TR-1252-1) Avail: NTIS HC A07/MF A01 CSCL 01C

The purpose is to determine the tailless aircraft performance improvements gained from relaxed static stability, to quantify this potential in terms of range-payload improvements, and to identify other possible operational and handling benefits or problems. Two configurations were chosen for the study: a modern high aspect ratio, short-chord wing proposed as a high-altitude long endurance (HALE) remotely piloted vehicle; a wider, lower aspect ratio, high volume wing suitable for internal stowage of all fuel and payload required for a manned long-range reconnaissance mission. Flying at best cruise altitude, both unstable configurations were found to have a 14 percent improvement in range and a 7 to 9 percent improvement in maximum endurance compared to the stable configurations. The unstable manned configuration also shows a 15 percent improvement in the 50 ft takeoff obstacle distance and an improved height response to elevator control. However, it is generally more deficient in control power due to its larger adverse aileron yaw and its higher takeoff and landing lift coefficient C(sub L), both due to the downward trimmed (vs. upward trimmed for stable configurations) trailing edge surfaces. Author

N89-21000# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
FLIGHT CONTROLLER DESIGN WITH NONLINEAR AERODYNAMICS, LARGE PARAMETER UNCERTAINTY AND PILOT COMPENSATION M.S. Thesis
THOMAS J. KOBYLARZ Dec. 1988 115 p
(AD-A202727; AFIT/GE/ENG/88D-19) Avail: NTIS HC A06/MF A01 CSCL 01D

Nonlinear Quantitative Feedback Theory (QFT), developed by Dr. Isaac Horowitz, is used to design a flight control system for the YF-16 aircraft. Upon completing this stability augmentation system (SAS) additional compensation is added to reduce pilot workload while improving handling qualities. The YF-16 uncertain plant is simulated with C (a blend of normal acceleration at pilot station and pitch rate) as the controlled output. The simulation includes the full six degree of freedom nonlinear dynamic equations of motion and aerodynamic data throughout the entire subsonic flight envelope. A technique is presented which enables the uncertain nonlinear YF-16 to be represented as a set of linear timer invariant plants which is equivalent to the nonlinear plant with respect to the set of acceptable outputs. Once this set of plants is obtained, a linear QFT controller is synthesized yielding fixed compensation which is extremely insensitive to varying flight conditions. Simulations in the time and frequency domains demonstrate that the desired performance is attained. Further work with real-time man-in-the-loop simulations should be accomplished to expand the area of pilot compensation. GRA

N89-21001# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
A DIGITAL RATE CONTROLLER FOR THE CONTROL RECONFIGURABLE COMBAT AIRCRAFT DESIGNED USING QUANTITATIVE FEEDBACK THEORY M.S. Thesis
KURT NYLE NEUMANN Dec. 1988 149 p
(AD-A203050; AFIT/GE/ENG/88D-33) Avail: NTIS HC A07/MF A01 CSCL 01D

The objective of this thesis is to develop a digital controller using Quantitative Feedback Theory for a fighter aircraft with unstable, nonminimum phase dynamics that meets performance specifications despite surface failures. Aircraft design trends for highly maneuverable fighter aircraft are relaxing stability requirements in order to increase performance in the transonic and supersonic regions. However, as a result, the aircraft is statically unstable in the subsonic region which makes the flight control system critical to flight safety. The conventional approach to the flight safety problem is to provide multiple redundancy throughout the fight control system. However, QFT provides an alternative to excessive hardware. The three controlled states are the pitch, roll, and yaw rates. A weighting matrix is derived which linearly combines the nine control surfaces into three control inputs. The plant is converted to a certain plane using the Hoffman algorithm. Three constant gain controllers and three prefilters are designed for a single flight condition of 0.9 Mach and 30000 ft altitude. The controllers and prefilters are transformed to the z plane for simulation purposes. The design is simulated with healthy plant and 24 combinations of surface failures. GRA

09

RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A89-33384*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS OF THE DEDICATED LASER VELOCIMETER SYSTEMS AT NASA - LANGLEY RESEARCH CENTER
JAMES F. MEYERS (NASA, Langley Research Center, Hampton, VA) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 4.12 (10 p.). refs

Three representative laser velocimeter systems used at NASA - Langley Research Center are described and analyzed. They range from a small orthogonal three component system used for detailed aerodynamic investigations to a large two component system used for investigations of complicated helicopter rotor flow fields. The components used in each system are described and analyzed for their contributions to the measurement uncertainty. Example flow field measurements are presented to illustrate the capabilities of these systems. Author

A89-33568
DESIGN ASPECTS OF A NAVAL RPV RECOVERY SYSTEM
D. R. TAYLOR (GEC Avionics, Ltd., Rochester, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Proceedings. Bristol, England, University of Bristol, 1988, p. 25.1-25.15.

The full potential of RPVs in naval operations cannot be realized until the performance advantages of fixed-wing air vehicles are combined with a reliable recovery system that can be accomodated by vessels no larger than frigates. Attention is presently given to the guidance-, capture-, retardation-, and restraint-phase problems of returning RPV shipboard recovery, given the ship environment's hydrodynamic motions, aerodynamic turbulence, and restricted space. Net and hook-and-wire methods are examined, and a version of the latter which employs a long, overboard-extending boom for parachute-decelerated RPV recovery is proposed. O.C.

A89-33569
LAUNCH, RECOVERY AND HANDLING SYSTEMS FOR VERTICAL TAKE-OFF AND LANDING UAVS OPERATING FROM SMALL SHIPS
JAY J. DOYLE (Indal Technologies, Inc., Mississauga, Canada) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 6.1-6.7. refs

Launch and recovery systems are proposed for shipboard operations of naval reconnaissance VTOL unmanned air vehicles, such as the CL-227 Sea Sentinel, in the case of ships as small as 4000-ton destroyers. These operations must remain possible at sea state 5, which in the destroyer's case can generate rolling motions of up to +/- 25 deg. The system presently defined furnishes complete postlanding security of the CL-227 during deck rolling motions as great as 31 deg. Self-activating probes incorporated into each of the landing gear legs of the CL-227 release spring-loaded fingers that open under the landing grid to prevent upward or lateral motion. O.C.

A89-33575
INTEGRATED MODULAR RPV GROUND STATION WITH REFERENCE TO THE 'RAVEN' PROJECT
R. WILLIS and S. M. HUDSON (Flight Refuelling, Ltd., Wimborne, England) IN: Remotely piloted vehicles; International Conference, 7th, Bristol, England, Sept. 12-14, 1988, Supplementary Papers. Bristol, England, University of Bristol, 1988, p. 24.1-24.11. Research supported by the Ministry of Defence Procurement Executive.

The performance requirements, development history, design features, and accomplishments to date of the RPV flight control ground station initially developed for the XRAE1, XRAE2, and Raven RPVs. The beyond-visual-range flight requirement for the controller led to the use of a radar-tracking system in conjunction with a ground station desktop computer for outer-loop control. An MVME 110 single-board computer was chosen as the basis of the dedicated system due to its flexibility, availability, and large capacity for future development. O.C.

A89-33630#
HIGH ENTHALPY TESTING IN HYPERSONIC SHOCK TUNNELS
B. ESSER, H. GROENIG, and H. OLIVIER (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) University of Texas, U.S. Air Force Academy, and GAMNI-SMAI, Joint Europe/U.S. Short Course in Hypersonics, 2nd, U.S. Air Force Academy, Colorado Springs, CO, Jan. 16-20, 1989, Paper. 93 p. refs

High-enthalpy hypersonic ground test facilities, such as shock tunnels, free piston shock tunnels, and gun tunnels are described. The performance of the Aachen tunnel is addressed with attention given to some shock tube data for equilibrium air. Simulation of flight conditions in shock tunnels is detailed. K.K.

A89-33760#
NEW STATIC ENGINE NOISE TEST TECHNIQUES WHICH REDUCE TEST TIME SIGNIFICANTLY
Y. ATVARS and D. M. LANE (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 15 p. refs
(AIAA PAPER 89-1127)

This paper examines the applicability of static-noise data-acquisition methods that can significantly reduce total test time, compared to current industry practices, without compromising data quantity or quality. Two methods are considered in which noise levels are recorded continuously as the engine power is advanced either smoothly or in steps through the operational power range, unlike in the common approach, where the engine power setting is arbitrarily stabilized for two minutes or more prior to steady-state noise recording. Test results are presented on engines from three different engine manufacturers and test facilities, in which the method of smooth continuous acceleration was used. The method in which the engine power is advanced in steps was also tried and was found to be very effective. Both methods reduce test time significantly and yield excellent quality data. I.S.

A89-33801
FULL-SCALE FATIGUE TESTING OF COMPONENTS AND STRUCTURES
KENNETH JAMES MARSH, ED. (National Engineering Laboratory, East Kilbride, Scotland) London and Stoneham, MA, Butterworths, 1988, 344 p. For individual items see A89-33802 to A89-33804.

The development and practice of full-scale fatigue testing in industrial design and development are discussed. The industries involved in aircraft structures, automotive components and systems, railway components, helicopter rotor heads, artillery gun structures, offshore structures and components, bridge components, military bridges, nuclear engineering, gas turbine components, mobile crane components and structures, ropes, and general mechanical engineering components are considered. The service operating environment, the design and operation of the Strongfloor Structural Testing Laboratory at NEL are also addressed. C.D.

A89-33802
FULL-SCALE FATIGUE TESTING OF AIRCRAFT STRUCTURES
P. R. EDWARDS (PP Data, Ltd., England) IN: Full-scale fatigue testing of components and structures. London and Stoneham, MA, Butterworths, 1988, p. 16-43. refs

The history of full-scale fatigue testing of aircraft structures is reviewed, and the design philosophy and justification of such testing are discussed. A detailed case study is given for the fatigue testing of the Concorde. It is concluded that it is possible to justify full-scale testing of aircraft structures on the basis of safety or economics, whether or not such tests are required for certification. For small military aircraft the safety case is particularly strong because of the difficulty in making designs fail-safe. The case study demonstrates that intelligently conducted tests can help in greatly extending the life of a fleet. C.D.

A89-33803
FATIGUE EVALUATION OF HELICOPTER ROTOR HEADS
R. L. C. GREAVES (Westland Helicopters, Ltd., Yeovil, England) IN: Full-scale fatigue testing of components and structures. London and Stoneham, MA, Butterworths, 1988, p. 77-97.

Methods of testing and evaluating the life of specific types of helicopter rotor heads are described. The nature of the loads on a rotor and the types of rotors considered are reviewed, and the flight measurement and analysis of the loads are addressed. The derivation of test loads is summarized, and fatigue test programs are discussed. The development of a universal rotor head test facility is described. C.D.

A89-33804
FATIGUE TESTING OF GAS TURBINE COMPONENTS
G. ASQUITH and A. C. PICKARD (Rolls-Royce, PLC, Derby, England) IN: Full-scale fatigue testing of components and structures. London and Stoneham, MA, Butterworths, 1988, p. 210-234. refs

Aspects of the fatigue testing of gas turbine components are discussed. Component life prediction and design requirements are summarized, and the determination of safe predicted total life and of safe crack propagation life are examined in detail. The full-scale component testing of gas turbine components is addressed. It is shown that a large number of variables can affect the lives of gas turbine components, and that full-scale component testing offers a means of ensuring that the most significant of these are taken into account in the procedure for safe-life estimation. C.D.

A89-34890#
RESULTS FROM LASER SHEET VISUALIZATION OF A PERIODIC ROTOR WAKE
A. BRAND, N. KOMERATH, and H. MCMAHON (Georgia Institute of Technology, Atlanta) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 438-443. Previously cited in issue 07, p. 955, Accession no. A88-22140. refs
(Contract DAAG29-82-K-0084)

A89-35217#
WALL-INTERFERENCE CORRECTIONS FOR PARACHUTES IN A CLOSED WIND TUNNEL
J. MICHAEL MACHA and ROBERT J. BUFFINGTON (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 97-103. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0900)

An extensive test program was conducted to gather information on wall-interference effects for parachutes in closed wind tunnels. Drag area and base pressure measurements were made for a set of ribbon parachutes of 7, 15, and 30 percent geometric porosity in six different wind tunnels, covering a geometric blockages from 2-35 percent. The resulting data have been used to formulate and validate approximate blockage correction equations based on the theory of Maskell (1963). The corrections are applicable to

single parachutes and clusters of two and three parachutes.
Author

N89-20955*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TEST TECHNIQUES: A SURVEY PAPER ON CRYOGENIC TUNNELS, ADAPTIVE WALL TEST SECTIONS, AND MAGNETIC SUSPENSION AND BALANCE SYSTEMS
ROBERT A. KILGORE, DAVID A. DRESS, STEPHEN W. D. WOLF, and COLIN P. BRITCHER (Old Dominion Univ., Norfolk, VA.) *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 705-740 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 14B

The ability to get good experimental data in wind tunnels is often compromised by things seemingly beyond our control. Inadequate Reynolds number, wall interference, and support interference are three of the major problems in wind tunnel testing. Techniques for solving these problems are available. Cryogenic wind tunnels solve the problem of low Reynolds number. Adaptive wall test sections can go a long way toward eliminating wall interference. A magnetic suspension and balance system (MSBS) completely eliminates support interference. Cryogenic tunnels, adaptive wall test sections, and MSBS are surveyed. A brief historical overview is given and the present state of development and application in each area is described. Author

N89-20957*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INSTRUMENTATION ADVANCES FOR TRANSONIC TESTING
PERCY J. BOBBITT *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 765-816 Mar. 1989
Avail: NTIS HC A22/MF A01 CSCL 14B

New and improved instrumentation, like new and improved wind tunnels, provide capabilities which stimulate innovative research and discovery. During the past few years there have been a number of instrumentation developments which have aided and abetted the acquisition of more accurate aerodynamic data and have led to new physical insights as well. Some of these advances are reviewed, particularly in the area of thin film gages, hot wire anemometry, and laser instrumentation. A description is given of the instruments and/or techniques and some sample results are shown. Author

N89-20961*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CAPABILITIES OF WIND TUNNELS WITH TWO-ADAPTIVE WALLS TO MINIMIZE BOUNDARY INTERFERENCE IN 3-D MODEL TESTING
RAINER REBSTOCK and EDWIN E. LEE, JR. *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 891-910 Mar. 1989 Sponsored in part by National Research Council
Avail: NTIS HC A22/MF A01 CSCL 14B

An initial wind tunnel test was made to validate a new wall adaptation method for 3-D models in test sections with two adaptive walls. First part of the adaptation strategy is an on-line assessment of wall interference at the model position. The wall induced blockage was very small at all test conditions. Lift interference occurred at higher angles of attack with the walls set aerodynamically straight. The adaptation of the top and bottom tunnel walls is aimed at achieving a correctable flow condition. The blockage was virtually zero throughout the wing planform after the wall adjustment. The lift curve measured with the walls adapted agreed very well with interference free data for Mach 0.7, regardless of the vertical position of the wing in the test section. The 2-D wall adaptation can significantly improve the correctability of 3-D model data. Nevertheless, residual spanwise variations of wall interference are inevitable. Author

N89-21002*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FLOWFIELD MEASUREMENTS IN THE NASA LEWIS RESEARCH CENTER 9- BY 15-FOOT LOW-SPEED WIND TUNNEL
CHRISTOPHER E. HUGHES Mar. 1989 78 p
(NASA-TM-100883; E-4116; NAS 1.15:100883) Avail: NTIS HC A05/MF A01 CSCL 14B

An experimental investigation was conducted in the NASA Lewis 9- by 15-Foot Low-Speed Wind Tunnel to determine the flow characteristics in the test section during wind tunnel operation. In the investigation, a 20-probe horizontally-mounted Pitot-static flow survey rake was used to obtain cross-sectional total and static pressure surveys at four axial locations in the test section. At each axial location, the cross-sectional flowfield surveys were made by repositioning the Pitot-static flow survey rake vertically. In addition, a calibration of the new wind tunnel rake instrumentation, used to determine the wind tunnel operating conditions, was performed. Boundary laser surveys were made at three axial locations in the test section. The investigation was conducted at tunnel Mach numbers 0.20, 0.15, 0.10, and 0.05. The test section profile results from the investigation indicate that fairly uniform total pressure profiles (outside the test section boundary layer) and fairly uniform static pressure and Mach number profiles (away from the test section walls and downstream of the test section entrance) exist throughout in the wind tunnel test section. Author

N89-21003# Systems Control Technology, Inc., Arlington, VA.
HELIPORT SYSTEM PLANNING GUIDELINES
DEBORAH PEISEN Apr. 1988 113 p
(Contract DTFA01-87-C-00014)
(AD-A199081; DOT/FAA/PM-87/33; DOT/FAA/PP-88/3) Avail: NTIS HC A06/MF A01 CSCL 01E

State and city governments generally realize that continued vitality depends on a steady expansion of industry and services as a function of planned growth. The helicopter is a proven catalyst for enhancement of those desired growth patterns. However, without the necessary support infrastructure, this positive contribution of the helicopter cannot be realized. Determining the need for such a support system can be achieved through an understanding of local helicopter activities and the metropolitan or state-wide socioeconomic dynamics in which they occur. This allows for data base development, including a fleet inventory, and analysis to provide a foundation for determining current, and forecasting future, helicopter activity and support facility requirements. Heliport planning is a relatively new field. Previous efforts, although based on proven fixed-wing airport methods, have produced a series of uncoordinated and nonstandardized products from many various individual planners and organizations. Consequently, the data collected and the analytical processes used have not been consistent or directly comparable. Fundamental planning criteria by which urban area heliport requirements may be assessed at any jurisdictional level are given Author

N89-21004*# Vigyan Research Associates, Inc., Hampton, VA.
PERFORMANCE OF THE ACTIVE SIDEWALL BOUNDARY-LAYER REMOVAL SYSTEM FOR THE LANGLEY 0.3-METER TRANSONIC CRYOGENIC TUNNEL
S. BALAKRISHNA, W. ALLEN KILGORE, and A. V. MURTHY Feb. 1989 26 p
(Contract NAS1-17919)
(NASA-CR-181793; NAS 1.26:181793) Avail: NTIS HC A03/MF A01 CSCL 14B

A performance evaluation of an active sidewall boundary-layer removal system for the Langley 0.3-m Transonic Cryogenic Tunnel (TCT) was evaluated in 1988. This system uses a compressor and two throttling digital valves to control the boundary-layer mass flow removal from the tunnel. The compressor operates near the maximum pressure ratio for all conditions. The system uses a surge prevention and flow recirculation scheme. A microprocessor based controller is used to provide the necessary mass flow and compressor pressure ratio control. Initial tests on the system

indicated problems in realizing smooth mass flow control while running the compressor at high speed and high pressure ratios. An alternate method has been conceived to realize boundary-layer mass flow control which avoids the recirculation of the compressor mass flow and operation near the compressor surge point. This scheme is based on varying the speed of the compressor for a sufficient pressure ratio to provide needed mass flow removal. The system has a mass flow removal capability of about 10 percent of test section flow at M = 0.3 and 4 percent at M = 0.8. The system performance has been evaluated in the form of the compressor map, and compressor tunnel interface characteristics covering most of the 0.3-m TCT operational envelope. Author

N89-21005# Naval Civil Engineering Lab., Port Hueneme, CA.
EXPERIMENTAL EXAMINATION OF THE AEROTHERMAL PERFORMANCE OF THE T-10 TEST CELL AT NAS (NAVAL AIR STATION), CUBI POINT Report, Oct. 1986 - Sep. 1987
C. A. KODRES, E. E. COOPER, and P. L. STONE Sep. 1988 140 p
(AD-A203887; NCEL-TN-1788) Avail: NTIS HC A07/MF A01 CSCL 14B

This report presents results of aerodynamic and thermodynamic tests conducted on the first standard Navy air-cooled T-10 test cell. Objectives of the tests were to: (1) Determine if aerodynamic and thermodynamic design objectives for the standard T-10 test cells were met; (2) Obtain data for comparing analytical predictions and validating analytical modeling techniques, and (3) Obtain baseline data of cell performance for use in case of future changes in design or operations. GRA

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A89-32948
FIRE EXTINGUISHING AGENTS FOR OXYGEN-ENRICHED ATMOSPHERES
DENNIS M. ZALLEN and EDWARD T. MOREHOUSE, JR. (USAF, Engineering and Services Center, Tyndall AFB, FL) IN: Flammability and sensitivity of materials in oxygen-enriched atmospheres; Proceedings of the Symposium, Cambridge, England, Apr. 6-8, 1987. Volume 3. Philadelphia, PA, American Society for Testing and Materials, 1988, p. 391-412. refs

Fire suppression agent requirements for extinguishing fires in oxygen-enriched atmospheres were determined by employing small-, medium-, large-, and full-scale test apparatus. The small- and medium-scale tests showed that a doubling of the oxygen concentration required five times more Halon to be extinguished. This trend agrees with Halon's chemical interference in the chain reaction of the combustion process and the increase in the flame radical pool caused by increased oxygen. For fires of similar size and intensity, the effect of oxygen enrichment of the cabin volume in the HC-131A was not as great as in the smaller compartments of the B-52, which presented a higher damage scenario. The full-scale tests showed that damage to the airframe was as important a factor in extinguishment as oxygen enrichment was. Author

A89-33454
PM SUPERALLOY TURBINE BLADES
S. W. K. SHAW (Inco Engineered Products, Ltd., Birmingham, England) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 3.1-3.22.

A development history and performance capability evaluation are presented for a large, forged gas turbine blade based on a modification of the P/M IN792 alloy, designated APK-6, which in addition to exhibiting creep rupture strength levels superior to cast IN792 at 650-750 C possesses the fatigue resistance of IN738LC at 600 C. This level of fatigue resistance is comparable to that of Nimonic 90. Two preferred compaction routes have been defined for the new alloy: HIP at 1160 C, followed by 1100 C extrusion, and direct extrusion of the loose powder at 1120 C. Directionally-recrystallized APK-6 yields a stress-rupture strength comparable to that of dispersion-strengthened Mar.M.002, for service lives of about 1000 hr at 980 C. O.C.

A89-33456
ADVANCED MICROSTRUCTURAL OBSERVATIONS OF GAS TURBINE P/M MATERIALS
M. JEANDIN, J. D. BARTOUT, and F. GRILLON (Paris, Ecole Nationale Superieure des Mines, Evry, France) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 6.1-6.13. refs

In situ SEM observations at temperatures of up to 1500 C have been performed on high-performance P/M alloys, in conjunction with TEM, in order to investigate such thermally-activated phenomena as: (1) the densification kinetics and microstructural modification of particles during the sintering of Ni-base superalloy powders; (2) the location, size and shape of recrystallized zones and the kinetics of recrystallization for Ni-base superalloys; and (3) the thermomechanical behavior of thermal barrier coatings deposited on a Ni-base superalloy and their microstructural features' evolution vs time and temperature. The principal sources of instrumentation errors were the need to operate under vacuum and to use thermal etching. A laser-heating system is recommended for future investigations. O.C.

A89-33463
SPRAY FORMED WASPALOY FOR DISC FORGINGS
H. PUSCHNIK, H. JAEGER, and F. HEINEMANN (Vereinigte Edelstahlwerke AG, Kapfenberg, Austria) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 14.1-14.7. refs

In the 'Osprey' spray-forming process, liquid metal is subjected to spray atomization by means of a high velocity inert gas jet and directed onto a circular plate. The disklike preform thus created can be directly forged into a gas turbine disk. Secondary phase particles and nonmetallic inclusions are finely dispersed in a fashion analogous to P/M materials; the preforms are also characterized by very low gas content. Tensile test results show the Osprey-produced disks to have, in addition to a tensile strength that is competitive with P/M and forged disks, both suitably high ductility and toughness values. O.C.

A89-33465
TITANIUM PM ATTRIBUTES AND POTENTIAL FOR AIRCRAFT ENGINE APPLICATIONS
G. E. WASIELEWSKI and A. M. JOHNSON (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 18.1-18.12. refs

The need of high-temperature, high-strength titanium alloys as lighter weight substitutes for nickel-base superalloys in aircraft engines has spurred interest in rapidly solidified (RS) titanium. The limitations of titanium ingot metallurgy and the potential of RS metallurgy are described. A review of the major RS powder-making processes evaluates the resultant powder attributes and significance relative to aircraft engine applications. The features of gas atomized and substrate quenched powder are described and the cooling rate effects analyzed. Consolidation methods aimed at preserving the RS powder features are reviewed and examples of property improvements are shown. Concerns and sources for powder contamination and their potential effects on properties are given. Aircraft engine payoffs and the need for lower cost high quality powder are discussed. Author

A89-33474
RAPIDLY SOLIDIFIED ALUMINUM ALLOYS FOR HIGH TEMPERATURE/HIGH STIFFNESS APPLICATIONS
PAUL S. GILMAN and SANTOSH K. DAS (Allied-Signal Metals and Ceramics Laboratory, Morristown, NJ) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 27.1-27.12. refs

Rapid solidification and consolidation technologies have been used to develop thermally stable intermetallic compounds in structural parts fabricated from quarternary, Al-Fe-V-Si alloys applicable to turbine engines, aircraft and missile structures, and similar elevated service temperature/corrosion resistance/elastic modulus-critical elements. The rapidly solidified alloys were produced by planar flow casting of the melt, followed by comminution of the ribbon thus obtained; they are characterized by the high volume fractions of silicides dispersed in the Al matrix. High tensile moduli and excellent corrosion resistance are obtained. O.C.

A89-33490
POTENTIAL APPLICATIONS FOR ADVANCED STRUCTURAL CERAMICS IN AERO GAS TURBINE ENGINES
S. NEWSAM (Rolls-Royce, PLC, Derby, England) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 43.1-43.18. refs

Structural engineering ceramics offer the promise of good high temperature mechanical properties, combined with low density, high temperature corrosion and oxidation resistance and in composite form a degree of toughness. This paper discusses the potential applications of ceramics in aero gas turbines and the engineering requirements which must be satisfied before the unique properties of this class of materials can be exploited and fully utilized in the gas turbine field. In addition the advantages and disadvantages of monolithic and reinforced ceramics are discussed and potential systems and major problem areas highlighted. Author

A89-34080
CERAMICS IN HIGH-TEMPERATURE GAS TURBINES (REVIEW) [KERAMIKA V VYSOKOTEMPERATURNYKH GTU /OBZOR/]
I. I. KIRILLOV, A. V. SUDAREV, and A. G. REZNIKOV (Leningradskii Metallicheskii Zavod, VTUZ, Leningrad, USSR) Promyshlennaia Teplotekhnika (ISSN 0204-3602), vol. 10, no. 6, 1988, p. 67-87. In Russian. refs

The possibilities afforded by the use of ceramic materials in gas turbines are examined. In particular, it is shown that high thermal efficiency can be achieved in high-temperature ceramic turbines as a result of the almost complete elimination of air cooling requirements. General principles for designing gas turbine components in ceramic materials are formulated. The design-related characteristics of ceramic components and the possibilities of combining ceramic and metal components are discussed. The current status of ceramic gas turbines and future prospects are briefly reviewed. V.L.

A89-34119
CHARACTERISTICS OF THE FORMATION OF BENZ(A)PYRENE IN THE COMBUSTION CHAMBERS OF AVIATION GAS TURBINE ENGINES [OB OSOBENNOSTIAKH OBRAZOVANIIA BENZ/A/PIRENA V KAMERAKH SGORANIIA AVIATSIONNYKH GTD]
IU. A. KNYSH, A. A. GORBATKO, A. V. IVLIEV, S. V. LUKACHEV, and V. G. ROZNO Fizika Goreniia i Vzryva (ISSN 0430-6228), vol. 24, Nov.-Dec. 1988, p. 33-37. In Russian. refs

The carcinogenic properties of the combustion products of aviation fuels are largely determined by the presence of the incompletely burned hydrocarbon or polynuclear compounds such as benz(a)pyrene. Here experimental data are presented on the formation of benz(a)pyrene in the combustion chambers of aviation gas turbine engines, and a phenomenological scheme is proposed which describes the process of benz(a)pyrene formation. It is shown, in particular, that the total content of benz(a)pyrene in the combustion products depends to a large degree on the efficiency of the afterburning process in the secondary zone of the combustion chamber. V.L.

A89-34120
SOME CHARACTERISTICS OF THE FORMATION OF CONTAMINANTS DURING THE COMBUSTION OF HYDROCARBON FUELS IN THE COMBUSTION CHAMBERS OF GAS TURBINE ENGINES [O NEKOTORYKH OSOBENNOSTIAKH OBRAZOVANIIA ZAGRIAZNIAIUSHCHIKH VESHCHESTV PRI SZHIGANII UGLEVODORODNYKH TOPLIV V KAMERAKH SGORANIIA GAZOTURBINNYKH DVIGATELEI]
V. P. SVINUKHOV Fizika Goreniia i Vzryva (ISSN 0430-6228), vol. 24, Nov.-Dec. 1988, p. 37-42. In Russian. refs

A89-34121
A SIMPLE ONE-DIMENSIONAL MODEL FOR THE EFFECT OF *AIR POLLUTION ON SUPERSONIC COMBUSTION* [PROSTAIA ODNOMERNAIA MODEL' VLIIANIIA ZAGRIAZNENNOSTI VOZDUKHA NA SVERKHZVUKOVOE GORENIIE]
S. I. BARANOVSKII, A. S. NADVORSKII, and D. D. ROMASHKOVA Fizika Goreniia i Vzryva (ISSN 0430-6228), vol. 24, Nov.-Dec. 1988, p. 42-51. In Russian. refs

An attempt is made to develop a numerical model describing the effect of the type of heating on the combustion of a hydrogen-air mixture in supersonic flow. It is shown, in particular that the enrichment of the mixture with oxygen is a necessary but not sufficient condition for the correct modeling of supersonic combustion using flame heating. Flame heating using a hydrocarbon fuel is shown to be preferable to heating with a hydrogen fuel. V.L.

A89-34122
EFFECT OF TURBULENCE ON THE COMBUSTION OF AN ATOMIZED LIQUID FUEL [VLIIANIE TURBULENTNOSTI NA GORENIE RASPYLENNOGO ZHIDKOGO TOPLIVA]
V. R. KUZNETSOV Fizika Goreniia i Vzryva (ISSN 0430-6228), vol. 24, Nov.-Dec. 1988, p. 51-57. In Russian. refs

The combustion of an atomized liquid fuel in turbulent flow is investigated analytically. First, the combustion of an individual fuel droplet completely entrained by the flow is analyzed with allowance for the effects of evaporation processes and free convection. The combustion process typical of the idling mode of aviation gas turbine engines is then examined with emphasis on the effect of the air excess ratio. It is shown, in particular, that as the air excess ratio decreases from infinity to 1, the combustion efficiency may change nonmonotonically. V.L.

A89-34894#
FUEL HOLDUP AND COMPONENT DIFFUSIVITY IN A COOLED CYLINDRICAL TANK
ERNST VON MEERWALL (Akron, University, OH), DALE SCHRUBEN (Texas A & M University, Kingsville), ANTHONY LEO, RICK BRUNO, and JOHN JOSHUA Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 465-469.

The precipitation of solid waxes from aircraft jet fuels in cylindrical tanks (pod wing tanks) at the low temperatures encountered in high-altitude flight has been experimentally modeled. The techniques used were a direct measurement of optical opacity and holdup in a simulated wing tank, ultrasound imaging, and diffusion measurements based on nuclear magnetic resonance. The work is intended to show the applicability of these techniques to the study of holdup in realistic systems, and to attempt qualitative correlation between their results. The morphology of the fuel precipitate and its permeability to the liquid fuel component are found to depend on cooling rate as well as on the final temperature. Author

A89-34933
EXPERIMENTAL INVESTIGATION OF THE THERMAL CONDUCTIVITY OF DISPERSED CERAMIC MATERIALS

G. P. PETERSON and L. S. FLETCHER (Texas A & M University, College Station) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 77-84. Research supported by AGIE Corp. refs

Several analytical methods are presented by means of which the effective thermal conductivities of prospective, extreme service-temperature gas turbine blade materials incorporating ceramic dispersions can be ascertained. The character and results of an experimental investigation of the effective thermal conductivity of four such materials are also presented; the materials are tungsten carbide-cobalt, tungsten-copper, silicon nitride, and titanium diboride, and mean effective thermal conductivities and their temperature dependences are defined in light of 300-900 K measurements. Analytical method results are compared with experimental ones. O.C.

A89-35224#
NEW LIGHTWEIGHT PARACHUTE FABRICS OF KEVLAR ARAMID FIBER
STEVEN D. BEARE (Du Pont de Nemours and Co., Wilmington, DE) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 143-147. refs
(AIAA PAPER 89-0911)

The 55-denier Kevlar fiber-based 'Style 172' parachute fabric, which weighs 1.1 oz/sq yd, yields 3 times the strength of nylon at the same weight and has the additional advantage of being nonmelting. The fabric's air permeability can be adjusted from 50 to 150 CFM/sq ft, depending on the application intended; attention is given to a primary ejection-system parachute application for USAF and U.S Navy aircraft that will reduce the probability of death and injury in 'fireball' situations. Additional decelerator applications under development for this fabric are weapons-delivery systems and aerospace payload-recovery systems in which strength/weight values are critical. O.C.

A89-35235#
A CRITICAL REVIEW OF THE STATE OF THE ART FOR MEASUREMENT OF STRESS IN PARACHUTE FABRICS
EUGENE E. NIEMI, JR. (Lowell, University, MA) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 211-221. refs
(AIAA PAPER 89-0925)

This paper presents a summary of the state of the art for measuring stresses in parachute fabrics. It reviews fabric properties and the relationships between stress and strain. The use of pressure measurements together with a known canopy gore shape to determine stresses is discussed. The most commonly used stress measuring device, the Omega sensor, is reviewed in detail, and some problems associated with its use are explained. Other types of stress or strain measuring transducers that have been used with parachutes, or that show potential for use with parachutes, are reviewed and principles of operation are explained. Recommendations are made for additional studies that should be conducted to obtain more information on parachute fabric stresses. Author

A89-35722
THE EFFECT OF STRESS RATIO ON THE NEAR-THRESHOLD FATIGUE CRACK GROWTH BEHAVIOR OF TI-8AL-1MO-1V AT ELEVATED TEMPERATURE
G. C. SALIVAR, J. E. HEINE (Florida Atlantic University, Boca Raton), and F. K. HAAKE (United Technologies Corp., Government Products Div., West Palm Beach, FL) Engineering Fracture Mechanics (ISSN 0013-7944), vol. 32, no. 5, 1989, p. 807-817. Research supported by the United Technologies Corp. refs
(Contract F33615-85-C-5050)

Computer-controlled decreasing stress intensity range tests using compact tension specimens were performed in order to study the effects of stress ratio and temperature on the near-threshold fatigue crack growth characteristics of Ti-8Al-1Mo-1V. Crack closure and the effective stress intensity range could account for the effects of stress ratio at constant temperature. It is noted that crack closure could not account for the effects of temperature at a fixed stress ratio of 0.1. R.R.

N89-20205*# Norfolk State Coll., VA. Dept. of Chemistry and Physics.
A (13)C NMR ANALYSIS OF THE EFFECTS OF ELECTRON RADIATION ON GRAPHITE/POLYETHERIMIDE COMPOSITES Final Report
MILTON W. FERGUSON 29 Mar. 1989 9 p
(Contract NCC1-115)
(NASA-CR-182818; NAS 1.26:182818) Avail: NTIS HC A02/MF A01 CSCL 11D

Initial investigations have been made into the use of high resolution nuclear magnetic resonance (NMR) for the characterization of radiation effects in graphite and Kevlar fibers, polymers, and the fiber/matrix interface in graphite/polyetherimide composites. Sample preparation techniques were refined. Essential equipment has been procured. A new NMR probe was constructed to increase the proton signal-to-noise ratio. Problem areas have been identified and plans developed to resolve them. Author

N89-20231# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
QUENCH SENSITIVITY OF AIRFRAME ALUMINUM ALLOYS
H. J. KOLKMAN, W. G. J. THART, and L. SCHRA 29 Jan. 1988 10 p Presented at the 8th International Conference on the Strength of Metals and Alloys, Tampere, Finland, 22-26 Aug. 1988
(NLR-MP-88003-U; ETN-89-94052) Avail: NTIS HC A02/MF A01

The quench sensitivity of six precipitation hardened aluminum alloys for aerospace applications was investigated and explained by means of transmission electron microscopy. The quench sensitivity is mainly caused by the solute depletion associated with heterogeneous precipitation at dispersoids for low quench rates. ESA

N89-21051*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FUEL-RICH CATALYTIC COMBUSTION OF JET-A FUEL-EQUIVALENCE RATIOS 5.0 TO 8.0
THEODORE A. BRABBS and CARMEN M. GRACIA-SALCEDO (Army Aviation Research and Development Command, Cleveland, OH.) May 1989 10 p Prepared for presentation at the Central States Meeting of the Combustion Inst., Dearborn, MI, 30 Apr. - 3 May 1989
(NASA-TM-101975; E-4675; AVSCOM-TR-89-C-001; NAS 1.15:101975) Avail: NTIS HC A02/MF A01 CSCL 21B

Fuel-rich catalytic combustion (E.R. greater than 5.0) is a unique technique for preheating a hydrocarbon fuel to temperatures much higher than those obtained by conventional heat exchangers. In addition to producing very reactive molecules, the process upgrades the structure of the fuel by the formation of hydrogen and smaller hydrocarbons and produces a cleaner burning fuel by removing some of the fuel carbon from the soot formation chain. With fuel-rich catalytic combustion as the first stage of a two stage combustion system, enhanced fuel properties can be utilized by both high speed engines, where time for ignition and complete combustion is limited, and engines where emission of thermal NO sub x is critical. Two-stage combustion (rich-lean) has been shown to be effective for NO sub x reduction in stationary burners where residence times are long enough to burn-up the soot formed in the first stage. Such residence times are not available in aircraft engines. Thus, the soot-free nature of the present process is critical for high speed engines. The successful application of fuel-rich catalytic combustion to Jet-A, a multicomponent fuel used in gas turbine combustors, is discusssed. Author

N89-21071# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
FUELS COMBUSTION RESEARCH Final Technical Report, 1 Oct. 1985 - 30 Sep. 1988
IRVIN GLASSMAN, FREDERICK L. DRYER, and FORMAN A. WILLIAMS 30 Nov. 1988 47 p
(Contract F49620-86-C-0006)
(AD-A204161; AFOSR-89-0087TR) Avail: NTIS HC A03/MF A01 CSCL 21D

Studies of near and slightly sooting inverse and normal co-flow diffusion flames determined aromatics as the key intermediates to soot formation. The extent of aromatic formation was correlated with the earlier Princeton smoke height test results. The effect of oxygen addition to tightly bound fuels (ethene, ethyne and benzene) in diffusion flames was found to accelerate the pyrolysis and thus the soothing tendency, but not to affect other fuels in the temperature range of soot formation. Flow reactor experiments determined oxidation kinetic results for the mono and dialkylated aromatic components of jet fuels. Succinctly, it was found that the alkyl chains are attached initially and in the case of dialkylated compounds not simultaneously. Mechanisms have been presented. Results on boron slurry droplet combustion were obtained and provided a basis for calculating when droplet disruption would occur. Questions with respect to boron cloud combustion addressed mechanisms of ignition and combustion in the regime of chemical kinetic control. GRA

N89-21125# Detroit Diesel Allison, Indianapolis, IN.
HIGH DENSITY FUEL EFFECTS Final Report, Sep. 1985 - Apr. 1988
N. K. RIZK, V. L. OECHSIE, P. T. ROSS, and H. C. MONGIA 18 Aug. 1988 174 p
(Contract F33615-86-C-2604)
(AD-A202426; DDA-EDR-13471; AFWAL-TR-88-2046) Avail: NTIS HC A08/MF A01 CSCL 21D

The purpose of this program was to determine, by combustor rig tests and data evaluation, the effects of the high density fuel properties on the performance and durability of the Allison T56-A-15 combustion system. Four high density fuels in addition to baseline JP4 were evaluated in the effort. The rig test program included: nozzle flow bench testing, aerothermal performance and wall temperature, flame stability and ignition, injector coking and plugging, and flow transient effect. The data evaluation effort involved the utilization of empirical correlations in addition to analytical multidimensional tools to analyze the performance of the combustor. The modifications required to optimize the performance with high density fuels were suggested and the expected improvement in performance was evaluated. GRA

N89-21130# Utah Univ., Salt Lake City. Dept. of Chemistry.
MODERN MULTIPLE-PULSE, HIGH FIELD NMR STUDIES OF HIGH DENSITY JET FUELS Final Report
DONALD W. ALDERMAN, JANET C. CURTIS, DAVID M. GRANT, CHARLES L. MAYNE, and RONALD J. PUGMIRE Aug. 1988 54 p
(Contract F33615-86-C-2643)
(AD-A203320; AFWAL-TR-88-2049) Avail: NTIS HC A04/MF A01 CSCL 21D

Modern high field nuclear magnetic resonance (NMR) spectroscopic techniques have been evaluated in order to assess the capabilities of such techniques for the study of jet fuels and related materials. The utility and quantitative aspects of spectral editing techniques were evaluated. The field of 2-dimensional NMR spectroscopy is growing rapidly and several existing 2-D techniques are quite attractive for jet fuel studies. The protonhomonuclear correlation experiment is shown to provide useful information even in complex fuels. The heteronuclear correlation (1H-13C) experiment permits one to sort out overlapping lines in both the proton and carbon frequency domains. The J-coupled 2-D experiment is very useful for characterizing the nature of the carbon resonances as C, CH, CH2 and CH3 groups in jet fuels. A combination of heteronuclear correlation and J-coupled 2-D experiments allow one to sort and identify the hundreds of resonance lines in jet fuels. The 2-D inadequate method was shown to be a particularly useful experiment for determining carbon-carbon connectivities. A combination of the heteronuclear correlation, J-coupled, and INADEQUATE 2-D experiments proved to be a very powerful combination of techniques for identifying all of the major structural types of fragments in the JP-4, JP5, and MIG-25 fuels. GRA

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A89-33354#
THE INFLUENCE OF A RADIAL SWIRL GENERATOR ON THE FLOW FIELD FROM A FUEL NOZZLE MODEL
CH. HASSA, E. BLUEMCKE, M. RACHNER, and H. EICKHOFF (DFVLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) IN: *International Symposium on Applications of* Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 4.1 (6 p.). Research supported by TECFLAM. refs

In the present investigation outlet velocity profiles of a radial swirl generator in a fuel nozzle model have been measured. The goal was to remove uncertainties concerning the prescription of inlet conditions for the numerical prediction of gas turbine combustor flows. It was found that the amount of swirl produced from the generator was greater than expected from calculation based on cascade theory. Two- and three-dimensional calculations of the flow from the fuel nozzle model incorporating the measured inlet velocity profiles are compared with measurements. Author

A89-33381#
COMPARISON OF LDA AND LTA APPLICATION FOR PROPELLER TESTS IN WIND TUNNELS
J. H. M. GOODEN and J. W. KOOI (Nationaal Lucht- en Ruimtevaartlaboratorium, Emmeloord, Netherlands) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 4.11 (6 p.). Research supported by the Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs

A two-component laser Doppler (LDA) and laser transit (LTA) anemometer have been compared under industrial testing conditions in the flow field of a propeller. Free-stream flow speed was 40 m/s. The propeller, diameter 0.73 m, was operated at 3500 and 6000 rpm. Axial and tangential velocities were measured in front of, between, and behind the propeller blades. Author

A89-33388#
PARTICLE IMAGE DISPLACEMENT VELOCIMETRY APPLIED IN HIGH SPEED FLOWS
C. S. MORAITIS and M. L. RIETHMULLER (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium) IN: International Symposium on Applications of Laser Anemometry to Fluid Mechanics, 4th, Lisbon, Portugal, July 11-14, 1988, Proceedings. Lisbon, Instituto Superior Tecnico, 1988, p. 7.14 (5 p.). refs

An experiment that demonstrated the applicability of particle-image-displacement velocimetry (PIDV) to high-speed flows is reported. The problems encountered, pertinent to seeding and laser sheet illumination, are highlighted, and the solutions given are described in detail. Author

A89-33402
SYMPOSIUM ON TURBULENCE, 11TH, UNIVERSITY OF MISSOURY-ROLLA, ROLLA, OCT. 17-19, 1988, PREPRINTS
Symposium sponsored by the University of Missouri-Rolla. Rolla, MO, University of Missouri-Rolla, 1988, 605 p. For individual items see A89-33403 to A89-33437.

Topics discussed include turbulence structure in wake and jet flows, and turbulence structure in confined flows. Papers are also presented on laser-Doppler anemometry methods, developments in measuring techniques, flows in complex geometries, and transonic and supersonic flows. B.J.

A89-33435* Missouri Univ., Rolla.
NASA LIDAR VELOCIMETRY MEASUREMENTS
RICHARD ANDERSON (Missouri-Rolla, University, Rolla) and JAMES BILBRO (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Symposium on Turbulence, 11th, Rolla, MO, Oct. 17-19, 1988, Preprints. Rolla, MO, University of Missouri-Rolla, 1988, p. I1-1 to I1-6. refs

A large number of turbulence experiments performed at the Marshall Space Flight Center are reviewed. These experiments include measurements of clear air turbulence, aircraft landing wakes, wind shear, and severe storm turbulence. Also discussed is a plan to orbit a lidar on a satellite in a north-south orbit to make daily worldwide wind measurements. B.J.

A89-33448
AIR FORCE TRIBOLOGY PROGRAMS
B. D. MCCONNELL (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: Engineered materials for advanced friction and wear applications; Proceedings of the International Conference, Gaithersburg, MD, Mar. 1-3, 1988. Metals Park, OH, ASM International, 1988, p. 187-190. Research supported by USAF. refs

The organizational structure, aims, and current status of USAF tribology research programs are surveyed. The DARPA fundamental research program on solid-lubricated ceramics includes studies of adhesion problems, atomic-level friction, molecular dynamics, diamond films, lubricious oxides, and advanced tribological test equipment. The efforts of the Air Force Office of Scientific Research focus on the characterization of thin films using advanced analytical techniques, whereas research for space applications includes work on the deposition of thin ultralow-friction films, surface coatings for lightweight high-strength gears and bearings, ion implantation methods, and the use of AES for in situ monitoring of surfaces during friction and wear tests. T.K.

A89-33461
STRUCTURE AND PROPERTIES OF FORGED ODS NICKEL-BASE SUPERALLOYS
E. GRUNDY (Doncasters Monk Bridge, Ltd., Leeds, England) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 12.1-12.10. refs

The forging of critical gas turbine parts from oxide dispersion strengthened (ODS), mechanically alloyed bar feedstock provides an extremely cost-effective means of component production. Additionally, there exists the flexibility to control the structural and property response of these thermomechanically processing-sensitive alloys. Preselection of processing parameters combined with postworking recrystallization treatments are used to develop longitudinal crystal structures of variable grain size and aspect ratios in the MA 754 stator vane alloy and the MA 6000 rotor blade alloy. Author

A89-33487
ARGON SHROUDED PLASMA COATINGS FOR GAS TURBINE APPLICATIONS
B. J. GILL (Union Carbide UK, Ltd., Swindon, England) IN: International Conference on PM Aerospace Materials, Lucerne, Switzerland, Nov. 2-4, 1987, Proceedings. Shrewsbury, England, MPR Publishing Services, Ltd., 1988, p. 40.1-40.18. refs

In this paper, the principles of argon shrouded plasma spraying and the selection of coating materials are considered together with some production-proven applications of the technology taken from the hot parts of a number of different gas turbines. The use of the argon shrouded plasma spray process in conjunction with MCrAlY alloys (where M is Ni, Co, or Fe) and oxide ceramics to produce high temperature thermal barrier systems is highlighed. Author

A89-33580#
HEAT TRANSFER IN GAS TURBINE COMBUSTORS
MARIA DA GRACA CARVALHO and PEDRO JORGE COELHO (Lisboa, Universidade Tecnica, Lisbon, Portugal) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 3, April 1989, p. 123-131. Research supported by the Instituto Nacional de Investigacao Cientifica and Calouste Gulbenkian Foundation. refs

The present paper is concerned with the prediction of the local flow, heat-transfer, and combustion processes inside a three-dimensional can combustor chamber of a gas turbine. A three-dimensional numerical solution technique is used to solve the governing time-averaged partial differential equations and the physical modeling for turbulence, combustion, and thermal radiation. Heat-transfer modeling is emphasized in this paper. A method to calculate the distribution of temperature, radiative heat flux, and total heat flux of the liner is described. The implications of neglecting radiative heat transfer in gas turbine combustion chamber calculations are discussed. The influence of working pressure on radiative heat transfer is investigated, comparing the radiative heat flux and temperature distribution of the liner for three different working pressures: 5, 15, and 25 bar. Both radiative and convective fluxes increase with pressure, mainly because of the increase of inlet air temperature and gas emissivity. The ratio of the fluxes to the energy supplied to the combustor is very small. However, the accurate assessment of the flux distribution is an essential prerequisite for the prediction of the liner temperature distribution and liner life. Author

A89-33621
FABRICATION OF SINTERED ALPHA-SIC TURBINE ENGINE COMPONENTS
R. W. OHNSORG and M. O. TEN EYCK (Standard Oil Engineered Materials Co., Niagara Falls, NY) IN: Silicon carbide '87; Proceedings of the Symposium, Columbus, OH, Aug. 2-5, 1987. Westerville, OH, American Ceramic Society, Inc., 1989, p. 367-386. refs

Sintered alpha-SiC turbine engine components have been fabricated using three primary forming procedures: wet-bag isostatic pressing followed by green machining, slip casting, and injection molding. A closed loop fabrication approach is presented which takes each of these three paths into account. Additional process iterations are discussed, which can be related to one of the three paths. The format enables the part designer and manufacturer to interact and determine which path is most suitable based on economic and performance considerations. R.B.

A89-33731*# AeroChem Research Labs., Inc., Princeton, NJ.
SIMULTANEOUS COMPUTATION OF JET TURBULENCE AND NOISE
C. H. BERMAN (AeroChem Research Laboratories, Inc., Princeton, NJ) and J. I. RAMOS (Carnegie-Mellon University, Pittsburgh, PA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. Research supported by NASA and New Jersey Commission on Science and Technology. refs
(AIAA PAPER 89-1091)

The existing flow computation methods, wave computation techniques, and theories based on noise source models are reviewed in order to assess the capabilities of numerical techniques to compute jet turbulence noise and understand the physical mechanisms governing it over a range of subsonic and supersonic nozzle exit conditions. In particular, attention is given to (1) methods for extrapolating near field information, obtained from flow computations, to the acoustic far field and (2) the numerical solution of the time-dependent Lilley equation. V.L.

A89-33741#
SONIC FATIGUE AND NONLINEAR RESPONSE OF STIFFENED PANELS
RIMAS VAICAITIS (Columbia University, NY) and SIU-TONG CHOI (Weidlinger Associates, New York) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 10 p. refs (AIAA PAPER 89-1101)

A theoretical study on nonlinear response of discretely stiffened panels to random pressures and thermal loads is presented in this paper. The random input pressures are simulated in time-space domain and the nonlinear equations of motion are solved numerically by a Monte Carlo type approach. In addition, preliminary estimates of sonic fatigue based on the nonlinear stress distribution of response peaks and fatigue data from constant amplitude tests are given. The numerical results include deflection and stress response time histories, spectral densities, root mean square values, crossing rates, probability distribution, peak distribution and fatigue damage. Author

A89-34126
NATURAL VIBRATIONS OF CYLINDRICAL SHELLS WITH A RECTANGULAR CUTOUT [SOBSTVENNYE KOLEBANIIA TSILINDRICHESKIKH OBOLOCHEK S PRIAMOUGOL'NYM VYREZOM]
V. N. BAKULIN and S. L. SNESAREV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 3-6. In Russian. refs

The effect of the dimensions of rectangular cutouts on the parameters of the natural vibrations of cylindrical shells is investigated numerically using the finite element method. The results are compared with experimental data and an analytical solution using an orthotropic cylindrical shell with Navier-type boundary conditions as an example. It is found that, for the shell considered here, an increase in the cutout dimensions has only a slight effect on the natural vibration of the shell. V.L.

A89-34128
THE LOAD-BEARING CAPACITY OF CLOSED-PROFILE OBLONG CYLINDRICAL SHELLS MADE OF A METAL/POLYMER COMPOSITE LAMINATE [NESUSHCHAIA SPOSOBNOST' DLINNYKH TSILINDRICHESKIKH OBOLOCHEK ZAMKNUTOGO PROFILIA, IZGOTOVLENNYKH IZ SLOISTOGO METALLOPOLIMERNOGO KOMPOZITA]
I. G. TEREGULOV and E. S. SIBGATULLIN Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 9-13. In Russian.

The limiting state of thin multilayer shells of arbitrary profile is investigated analytically. The shell considered here is made of alternating layers of an aluminum alloy and a polymer composite; the external load acting on the shell is reduced to an axial force and a torque. The results obtained are presented in the form of tables and graphs. V.L.

A89-34129
FORMULATION AND SOLUTION OF AXISYMMETRIC PROBLEMS IN THE STATICS OF MULTILAYER SHELLS OF REVOLUTION WITH CONTACT INTERACTION BETWEEN LAYERS [POSTANOVKA I RESHENIE OSESIMMETRICHNYKH ZADACH STATIKI MNOGOSLOINYKH OBOLOCHEK VRASHCHENIIA PRI KONTAKTNOM VZAIMODEISTVII SLOEV]
V. A. FIRSOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 13-17. In Russian. refs

The mechanics of the static deformation of multilayer shells of revolution is analyzed from the standpoint of contact problems. An axisymmetric boundary value problem is stated for the mean relative layer thickness and a linear approximation of displacement vectors over the thickness of each layer. Calculations are carried for a real structure to demonstrate the approach proposed here. V.L.

A89-34136
AN EXPERIMENTAL STUDY OF THE RATE CHARACTERISTICS OF BRUSH SEALS IN COMPARISON WITH LABYRINTH SEALS [EKSPERIMENTAL'NOE ISSLEDOVANIE RASKHODNYKH KHARAKTERISTIK SHCHETOCHNOGO UPLOTNENIIA I SRAVNENIE S LABIRINTNYM UPLOTNENIEM]
G. M. GORELOV, V. E. REZNIK, and V. I. TSIBIZOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 43-46. In Russian.

The effect of the geometrical parameters of brush seals on the flow rate characteristic is investigated experimentally, and the results are compared with the rate characteristic of a known labyrinth seal. It is shown that the efficiency of brush seals is higher than that of labyrinth seals. A study of the thermal state of brush seals indicates that, despite the lower flow rate of air, sufficient cooling of the brush wires is achieved. V.L.

A89-34144
ADAPTIVE CONTROL OF THE GRINDING OF LARGE GAS TURBINE BLADES [ADAPTIVNOE UPRAVLENIE SHLIFOVANIEM PERA KRUPNOGABARITNYKH LOPATOK GTD]
L. T. MOISEEVA, F. S. IUNUSOV, and A. N. LUNEV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 77-80. In Russian.

A fully automated process for the dimensional grinding of large gas turbine blades has been developed, with the shaping of the blades controlled adaptively based on deformations in excess of the allowance and based on allowance fluctuations. Formulas are presented for determining and predicting deformations from the cutting forces. A model is developed and used in a series of simulations aimed at the evaluation and optimization of different system operation modes. V.L.

A89-34154
ASSESSMENT OF THE ADEQUACY OF BEARING LUBRICATION IN A GAS TURBINE ENGINE THROUGH OPENINGS IN THE ROTATING SHAFT [OTSENKA DOSTATOCHNOSTI SMAZKI PODSHIPNIKA GTD CHEREZ OTVERSTIIA VO VRASHCHAIUSHCHEMSIA VALU]
V. N. OSIPOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 98-100. In Russian.

A lubrication system for the rotor transmission bearings of gas turbines whereby the lubricant is supplied to the bearings through openings in the rotating shaft is examined as a promising substitute for the presently used spray lubrication system. Here, calculations are made to determine the adequacy of lubricant supply to the bearings in such a system. It is shown that the lubrication system proposed here provides for a more complete utilization of the oil in comparison with spray lubrication, which results in lower bearing temperatures V.L.

A89-34155
EFFECT OF THE BLADE HEIGHT AT THE EXIT OF THE SHROUDED ROTOR OF A RADIAL-FLOW CENTRIPETAL MICROTURBINE ON THE TURBINE EFFICIENCY [VLIIANIE VYSOTY LOPATKI NA VYKHODE IZ OBANDAZHENNOGO RABOCHEGO KOLESA RADIAL'NOI TSENTROSTREMITEL'NOI MIKROTURBINY NA EE KPD]
N. T. TIKHONOV and V. N. MATVEEV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 100, 101. In Russian.

A89-34159
ENSURING THE QUALITY OF THE COVERING SURFACE IN THE CASE OF RIVETED JOINTS WITH HIGH RADIAL INTERFERENCE [OBESPECHENIE KACHESTVA POVERKHNOSTI OBSHIVKI PRI VYPOLNENII ZAKLEPOCHNYKH SOEDINENII S VYSOKIM RADIAL'NYM NATIAGOM]
A. I. IARKOVETS, V. A. ZVIAGINTSEV, and V. Z. KONDRASHOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 108-110. In Russian.

The objective of the study was to determine the conditions under which the residual stresses produced by the interference fit

have a favorable effect on the life of the structure without causing any undesirable distortions of the airframe covering surface geometry. By using the superposition principle and treating a riveted joint as a certain inhomogeneity producing the stress-strain state in a solid plate, an expression is obtained for displacements in a plate with a system of m+1 joints; an expression for determining the critical values of the equivalent radial interference is then derived. The method is tested for the case of single joints in D16T panels made with 4-mm rivets of V65 alloy. V.L.

A89-34738
APPLICATIONS OF A GENERALIZED PRESSURE CORRECTION ALGORITHM FOR FLOWS IN COMPLICATED GEOMETRIES
W. SHYY (Florida, University, Gainesville) and M. E. BRAATEN (GE Research and Development Center, Schenectady, NY) IN: Advances and applications in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 109-119. refs

An overview is given of recent progress in developing a unified numerical algorithm capable of solving flow over a wide range of Mach and Reynolds numbers in complex geometries. The algorithm is based on the pressure correction method, combined treatment of the Cartesian and contravariant velocity components on arbitrary coordinates, and second-order accurate discretization. A number of two- and three-dimensional flow problems including the effects of electric currents, turbulence, combustion, multiple phases, and compressibility are presented to demonstrate the capability of the present algorithm. Some related technical issues, such as the skewness of the grid distribution and the promise of parallel computation, are also addressed. Author

A89-34794*# Texas A&M Univ., College Station.
ANNULAR HONEYCOMB SEALS: TEST RESULTS FOR LEAKAGE AND ROTORDYNAMIC COEFFICIENTS - COMPARISONS TO LABYRINTH AND SMOOTH CONFIGURATIONS
D. CHILDS, D. ELROD, and K. HALE (Texas A & M University, College Station) ASME, Transactions, Journal of Tribology (ISSN 0742-4787), vol. 111, April 1989, p. 293-300; Discussion, p. 300, 301. refs
(Contract NAG3-181; F49620-82-K-0033)
(ASME PAPER 88-TRIB-35)

Test results are presented for leakage and rotordynamic coefficients for seven honeycomb seals. All seals have the same radius, length, and clearance; however, the cell depths and diameters are varied. Rotordynamic data, which are presented, consist of the direct and cross-coupled stiffness coefficients and the direct damping coefficients. The rotordynamic-coefficient data show a considerable sensitivity to changes in cell dimensions; however, no clear trends are identifiable. Comparisons of test data for the honeycomb seals with labyrinth and smooth annular seals shows the honeycomb seal had the best sealing (minimum leakage) performance, followed in order by the labyrinth and smooth seals. For prerotated fluids entering the seal, in the direction of shaft rotation, the honeycomb seal has the best rotordynamic stability followed in order by the labyrinth and smooth. For no prerotation, or fluid prerotation against shaft rotation, the labyrinth seal has the best rotordynamic stability followed in order by the smooth and honeycomb seals. Author

A89-34798*# Texas A&M Univ., College Station.
AN ENTRANCE REGION FRICTION FACTOR MODEL APPLIED TO ANNULAR SEAL ANALYSIS - THEORY VERSUS EXPERIMENT FOR SMOOTH AND HONEYCOMB SEALS
D. ELROD, C. NELSON, and D. CHILDS (Texas A & M University, College Station) ASME, Transactions, Journal of Tribology (ISSN 0742-4787), vol. 111, April 1989, p. 337-343. refs
(Contract NAG3-181)
(ASME PAPER 88-TRIB-41)

A friction factor model is developed for the entrance-region of a duct. The model is used in an annular gas seal analysis similar to Nelson's (1984). Predictions of the analysis are compared to experimental results for a smooth-stator/smooth-rotor seal and three honeycomb-stator/smooth-rotor seals. The model predicts a leakage and direct damping well. The model overpredicts the dependence of cross-coupled stiffness on fluid prerotation. The model predicts direct stiffness poorly. Author

A89-34867#
ON THE DESIGN OF BIAXIALLY STIFFENED COMPOSITE PLATES
F. H. HO (BFGoodrich Co., Aerospace Div., Brecksville, OH) IN: Advanced composites and processing technology; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 51-54. refs

The development of an integrally fabricated, biaxially stiffened composite airframe primary structure entails thesolution of the problem posed by the discontinuity of the tensile load path at the stiffener intersections. The present treatment of the problem increases the web height of the secondary stiffener at cross-over sections. It is stressed that the added stiffener height should be just sufficient to satisfy strength requirements at the cutout. The overall advantage of the quasi-isotropic lamination has been demonstrated for the case of the design merit index employed. O.C.

A89-34909
DIRECT NUMERICAL SIMULATION OF A THREE-DIMENSIONAL TURBULENT BOUNDARY LAYER
P. MOIN, S. SHIH, O. SENDSTAD, and D. DRIVER (Stanford University, CA) IN: Recent developments in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 139-145. refs
(Contract AF-AFOSR-87-0285)

The effect of a suddenly imposed transverse pressure gradient on a fully developed planar two-dimensional channel flow at Re = 3300 is investigated by means of numerical simulations. The spectrum method of Kim et al. (1987) is implemented on a 128 x 128 x 128 grid capable of resolving all turbulent scales; no subgrid or turbulence models are required. Ensemble-averaged results from 14 simulation runs are presented in graphs and briefly characterized. Good agreement with published experimental data is demonstrated. T.K.

A89-34912* Scientific Research Associates, Inc., Glastonbury, CT.
BIPOLAR COORDINATES FOR COMPUTATION OF TRANSITION DUCT FLOWS
R. K. MADABHUSHI and R. LEVY (Scientific Research Associates, Inc., Glastonbury, CT) IN: Recent developments in computational fluid dynamics; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 185-192. refs
(Contract NAS3-24224)

Numerical simulation techniques for flows in jet-engine transition ducts with changing cross sections are developed and demonstrated. The boundary-conforming grids required are generated using bipolar coordinates, and the singularities arising at the no-slip boundaries are treated as described by de Vahl Davis (1979) and Tsai and Levy (1987). Grids for several typical configurations are employed in computations with the three-dimensional laminar/turbulent viscous-flow solver of Levy et al. (1983), and the results are presented graphically. The scheme used to deal with singularities is shown to be robust, suggesting that the bipolar grids may be applicable to Navier-Stokes computations. T.K.

A89-34926* General Electric Co., Fairfield, CT.
HEAT TRANSFER IN GAS TURBINE ENGINES AND THREE-DIMENSIONAL FLOWS; PROCEEDINGS OF THE SYMPOSIUM, ASME WINTER ANNUAL MEETING, CHICAGO, IL, NOV. 27-DEC. 2, 1988
E. ELOVIC, ED. (General Electric Co., Fairfield, CT), J. E. O'BRIEN, ED. (NASA, Lewis Research Center, Cleveland, OH), and D. W. PEPPER, ED. (Marquardt Co., Van Nuys, CA) Meeting sponsored by ASME, Heat Transfer Division. New York, American Society of Mechanical Engineers, 1988, 127 p. For individual items see A89-34927 to A89-34935.

The present conference on heat transfer characteristics of gas turbines and three-dimensional flows discusses velocity-temperature fluctuation correlations at the flow stagnation flow of a circular cylinder in turbulent flow, heat transfer across turbulent boundary layers with pressure gradients, the effect of jet grid turbulence on boundary layer heat transfer, and heat transfer characteristics predictions for discrete-hole film cooling. Also discussed are local heat transfer in internally cooled turbine airfoil leading edges, secondary flows in vane cascades and curved ducts, three-dimensional numerical modeling in gas turbine coal combustor design, numerical and experimental results for tube-fin heat exchanger airflow and heating characteristics, and the computation of external hypersonic three-dimensional flow field and heat transfer characteristics. O.C.

A89-34928* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECTS OF WAKE PASSING ON STAGNATION REGION HEAT TRANSFER
J. E. O'BRIEN (NASA, Lewis Research Center, Cleveland, OH) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 17-28. refs

In the present experimental study, an annular-flow wind tunnel fitted with a spoked-wheel wake generator was used to ascertain both time-averaged and time-resolved effects of wake passing in a cylinder stagnation region; the cylindrical spokes generated wakes simulating those of a turbine inlet guide vanes. The time-averaged heat transfer results obtained indicate an asymmetric heat-transfer coefficient distribution about the stagnation line, with higher heat-transfer coefficients on the side corresponding to the suction side of the turbine blade. Spectra of the hot-film records indicate that vortex-shedding is a major contributor to the unsteady buffeting of the test-cylinder boundary layer at circumferential stations located at both + and -60 deg from the stagnation line, despite making only a minor contribution to the stagnation line itself. O.C.

A89-34930
EFFECT OF JET GRID TURBULENCE ON TURBULENT BOUNDARY LAYER HEAT TRANSFER
C. D. YOUNG and J. C. HAN (Texas A & M University, College Station) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 37-44. refs
(Contract F33615-86-C-2723)

A wind tunnel with a biplanar, square-mesh round-tube grid for uniform, controllable-flow rate jet injection in either coflow or counterflow fashion is presently used to ascertain the effect of high freestream turbulence on turbulent boundary layer heat transfer. A flat plate section instrumented with foil-thermocouples is located behind the jet grid. The surface Stanton numbers with the counterflow and coflow injections are, respectively, about 45 and 25 percent higher than the zero turbulence correlation in the fully turbulent region. The effects of length-scale and low Reynolds number on the surface Stanton number are discussed. O.C.

A89-34931
PREDICTION OF HEAT TRANSFER CHARACTERISTICS OF DISCRETE HOLE FILM COOLING - ONE ROW OF INJECTION INTO A TURBULENT BOUNDARY LAYER
S. YAVUZKURT (Pennsylvania State University, University Park) and D. K. TAFTI IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 45-52. Research supported by Textron Lycoming. refs

Predictions of spanwise averaged effectiveness and heat-transfer coefficients are presently made on the basis of a two-dimensional injection model for the discrete-hole injection process that is incorporated in a two-dimensional boundary layer code using the low Reynolds number version of the k-epsilon model of turbulence. Attention is given to the case of one row of injection into a turbulent boundary layer. Two constants derived from experimental data are employed: the aerodynamic drag coefficient, controlling the jet penetration into the boundary layer, and the entrainment fraction, which simulates the effect of three-dimensional entrainment on the temperature profile. Velocity and temperature profiles are in good agreement with experimental data. O.C.

A89-34932
LOCAL HEAT TRANSFER IN INTERNALLY COOLED TURBINE AIRFOIL LEADING EDGE REGIONS. I - IMPINGEMENT COOLING WITHOUT FILM COOLANT EXTRACTION. II - IMPINGEMENT COOLING WITH FILM COOLANT EXTRACTION
R. S. BUNKER and D. E. METZGER (Arizona State University, Tempe) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 53-63. refs

The highly localized internal heat transfer characteristics of large-scale models of impingement-cooled turbine blade leading edge regions presently studied derives its cooling from a single line of equally-spaced multiple jets aimed at the leading-edge apex, and exiting the leading-edge region in the opposite or chordwise direction. Detailed two-dimensional local surface Nusselt number distributions have been obtained with temperature-indicating coatings. Results indicate generally increasing heat transfer with the 0.6 power of jet Reynolds number. In the second part of this study, in which the same cooling process is used in conjunction with the extraction of the coolant fluid, the results obtained indicate that heat transfer is primarily dependent on jet Reynolds number, with smaller influences from the flow-extraction rate. O.C.

A89-34935
COMPUTATION OF EXTERNAL, HYPERSONIC, THREE-DIMENSIONAL FLOWFIELD AND HEAT TRANSFER
A. BALAKRISHNAN (MCAT Institute, San Jose, CA) IN: Heat transfer in gas turbine engines and three-dimensional flows; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 115-122. refs

Hypersonic and equilibrium flowfields and heat-transfer rates around a blunt-nosed configuration are calculated by solving the Euler equations and thin-layer Navier-Stokes equations. The equilibrium thermodynamic and transport properties of the gas mixture are introduced into the numerical procedure by way of tables. Shock stand-off distances, normalized pressures, densities, and temperatures around a sphere, for Mach numbers of 10, 15, and 20, and at altitudes ranging from 20 to 80 km, are presented for inviscid flow. Laminar heat-transfer rates for several Mach numbers are computed. Computed stagnation-point heat-transfer results compare well with an engineering correlation and also with a viscous shock-layer solution. Computed heat-transfer distributions around the body compare well with experimental data. Author

A89-35004
COMPRESSIBLE FLOW LOSSES IN BRANCHED DUCTS

N. I. ABOU-HAIDAR and S. L. DIXON (Liverpool, University, England) IN: Collected papers in heat transfer 1988; Proceedings of the ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 17-23. refs

Investigation of the additional total pressure losses occurring at the junction of various branched ducts has been made both analytically and experimentally. Experimental results are presented for five different dividing flow geometries of a lateral branch off a straight duct. All duct intersections tested were sharp-edged. Dry air was the working fluid. Analysis of the results confirms the expected strong and increasingly adverse influence of compressibility at values of Mach number higher than 0.6.

Author

A89-35074
QUANTITATIVE FRACTOGRAPHY - POSSIBILITIES AND APPLICATIONS IN AIRCRAFT RESEARCH

I. NEDBAL, J. KUNZ, and J. SIEGL (Ceske Vysoke Uceni Technicke, Prague, Czechoslovakia) IN: Basic mechanisms in fatigue of metals; Proceedings of the International Colloquium, Brno, Czechoslovakia, Apr. 12-14, 1988. Amsterdam, Elsevier, 1988, p. 393-403. refs

The paper reviews methods of fatigue failure fractography developed for reconstitution of fatigue crack kinetics. Some results of fractographic analysis of failured aircraft structures are presented. It points out the importance of relation between macro- and microscopic fatigue crack propagation. The unacceptability of the assumption of macroscopic crack growth rate and striation spacing equality is illustrated by experimental data acquired on AlCu4Mgl (type 2024) sheet specimens, with the application in case study of the aircraft fuselage skin part failure. Author

A89-35081
MICRO RADIOGRAPHY AND TOMOGRAPHY FOR HIGH RESOLUTION NDT OF ADVANCED MATERIALS AND MICROSTRUCTURAL COMPONENTS

M. MAISL, H. REITER, and P. HOELLER (Fraunhofer-Institut fuer zerstoerungsfreie Pruefverfahren; Saarland, Universitaet, Saarbruecken, Federal Republic of Germany) IN: New directions in the nondestructive evaluation of advanced materials; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 29-33.

The application of microradiography and microcomputed tomography for the NDT of high strength ceramics and fiber-reinforced composites is discussed. Radiography with microfocal X-ray tubes provides high-resolution radiographs using the direct projection technique. Tomography produces high-contrast images of sections of an object, and results are presented using a tomographic unit with a resolution of the order of magnitude of 20 microns. R.R.

A89-35097#
AEROELASTIC DIVERGENCE OF FRONT-FREE-AFT-FIXED ELASTIC STRIP PARALLEL TO UNIFORM FLOW

YUZO YAMAMOTO (Gifu National College of Technology, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 31, Feb. 1989, p. 188-194. refs

The static instability of a slender free-fixed elastic strip in a uniform air stream whose free end is the leading edge is studied. The analysis is performed using slender body aerodynamic theory and beam theory. Both the static aeroelastic divergence speed and the divergence mode are derived. Low speed wind tunnel tests for the present problem were done. The strips used in these tests were thin copper plates and thin aluminum plates. It is shown that the divergence speed based on linear lift is higher than the one based on nonlinear lift. Author

A89-35146
DIVERGENCE INSTABILITY OF REINFORCED COMPOSITE CYLINDRICAL SHELLS

V. BIRMAN (New Orleans, University, LA) IN: Recent advances in the macro- and micro-mechanics of composite materials structures; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 169-175. refs

Divergence instability of a simply supported orthotropic composite shell reinforced in both axial and circumferential directions is considered. The shell is subject to an axial static load and to an action of an outside supersonic gas flow in the direction parallel to the shell axis. Two variants of the solution considered in the paper include discrete widely spaced stiffeners and closely spaced stiffeners; the latter case can be treated using a smeared stiffeners technique. It is proven that divergence instability of shells treated by smeared stiffeners technique can occur only if they are subject to axial compressive loads exceeding the static buckling value. Author

A89-35237#
PARACHUTE DRAWING STANDARDS CURRENTLY IN USE AT SANDIA NATIONAL LABORATORIES

KENNETH L. RONQUILLO (Sandia National Laboratories, Albuquerque, NM) IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 233-241.
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-0927)

A method of making comprehensive parachute drawings has been established at Sandia National Laboratories. This method uses some of the basic, standardized and conventional drawing practices used in making mechanical drawings. This method also introduces new drafting techniques unique to parachute drawings. Author

A89-35247#
AN EXPRESSION FOR DYNAMIC STRAIN IN A 'WEAK LINK'

GEORGE A. BARNARD IN: AIAA Aerodynamic Decelerator Systems Technology Conference, 10th, Cocoa Beach, FL, Apr. 18-20, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 310-318.
(AIAA PAPER 89-0942)

A 'weak link' is represented by a break cord or a lanyard used to control a sequence of events during deployment of a parachute. In this paper, a closed-form analytical solution is presented for the asymptotic strain state of a weak link between stronger bounding members. The convergence interval and convergence time are defined. For typical properties of materials used in high-speed parachutes, the strain state of such a link is accurately represented by its asymptotic value because of the rapid convergence of the solution. A sample calculation is presented to demonstrate the use of the analysis in designing break links and pull cords for fast-moving systems. Author

A89-35654
PROSPECTS FOR THE APPLICATION OF HOLOGRAPHIC INTERFEROMETRY TO THE STUDY OF THE RESONANT VIBRATIONS OF COMPLEX SYSTEMS [O PERSPEKTIVAKH PRIMENENIIA METODA GOLOGRAFICHESKOI INTERFEROMETRII K ISSLEDOVANIIU REZONANSNYKH KOLEBANII SLOZHNYKH SISTEM]

I. F. OBRAZTSOV and V. A. SMIRNOV Raschety na Prochnost', no. 28, 1988, p. 134-151. In Russian.

Results of holographic interferometry studies of the behavior of plates, shells, and complex three-dimensional models of mechanical systems subjected to periodic dynamic loading are reported. Examples are presented to demonstrate the possibility of the vibration of different parts of the same structure at different frequencies. Photographs of holograms are presented. V.L.

N89-20355*# Ohio State Univ., Columbus. ElectroScience Lab.
ELECTROMAGNETIC PROPERTIES OF ICE COATED SURFACES Semiannual Report

A. DOMINICK, E. WALTON, N. WANG, and L. BEARD Feb. 1989 19 p

(Contract NSG-3913)
(NASA-CR-184780; NAS 1.26:184780; ESL-720964-2) Avail: NTIS HC A03/MF A01 CSCL 20N

The electromagnetic scattering from ice coated structures is examined. The influence of ice is shown from a measurement standpoint and related to a simple analytical model. A hardware system for the realistic measurement of ice coated structures is also being developed to use in an existing NASA Lewis icing tunnel. Presently, initial measurements have been performed with a simulated tunnel to aid in the development. Author

N89-20363*# Ohio State Univ., Columbus. ElectroScience Lab.
IMPROVED COMPUTER SIMULATION OF THE TCAS 3 CIRCULAR ARRAY MOUNTED ON AN AIRCRAFT
R. G. ROJAS, Y. C. CHEN, and WALTER D. BURNSIDE Mar. 1989 191 p
(Contract NSG-1498)
(NASA-CR-184907; NAS 1.26:184907; ELS-TR-716199-12)
Avail: NTIS HC A09/MF A01 CSCL 20N

The Traffic advisory and Collision Avoidance System (TCAS) is being developed by the Federal Aviation Administration (FAA) to assist aircraft pilots in mid-air collision avoidance. This report concentrates on the computer simulation of the enchanced TCAS 2 systems mounted on a Boeing 727. First, the moment method is used to obtain an accurate model for the enhanced TCAS 2 antenna array. Then, the OSU Aircraft Code is used to generate theoretical radiation patterns of this model mounted on a simulated Boeing 727 model. Scattering error curves obtained from these patterns can be used to evaluate the performance of this system in determining the angular position of another aircraft with respect to the TCAS-equipped aircraft. Finally, the tracking of another aircraft is simulated when the TCAS-equipped aircraft follows a prescribed escape curve. In short, the computer models developed in this report have generality, completeness and yield reasonable results. Author

N89-20386*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN AIRFOIL PITCH APPARATUS-MODELING AND CONTROL DESIGN
DANIEL R. ANDREWS Mar. 1989 13 p Prepared for presentation at the 35th Instrument Society of America Instrumentation Symposium, Orlando, FL, 1-4 May 1989 Submitted for publication
(NASA-TM-101076; A-89051; NAS 1.15:101076) Avail: NTIS HC A03/MF A01 CSCL 09C

The study of dynamic stall of rapidly pitching airfoils is being conducted at NASA Ames Research Center. Understanding this physical phenomenon will aid in improving the maneuverability of fighter aircraft as well as civilian aircraft. A wind tunnel device which can linearly pitch and control an airfoil with rapid dynamic response is needed for such tests. To develop a mechanism capable of high accelerations, an accurate model and control system is created. The model contains mathematical representations of the mechanical system, including mass, spring, and damping characteristics for each structural element, as well as coulomb friction and servovalve saturation. Electrical components, both digital and analog, linear and nonlinear, are simulated. The implementation of such a high-performance system requires detailed control design as well as state-of-the-art components. This paper describes the system model, states the system requirements, and presents results of its theoretical performance which maximizes the structural and hydraulic aspects of this system. Author

N89-20409*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UPDATED USERS' GUIDE FOR TAWFIVE WITH MULTIGRID
N. DUANE MELSON and CRAIG L. STREETT Washington May 1989 68 p
(NASA-TM-4109; L-16543; NAS 1.15:4109) Avail: NTIS HC A04/MF A01 CSCL 20D

A program for the Transonic Analysis of a Wing and Fuselage with Interacted Viscous Effects (TAWFIVE) was improved by the incorporation of multigrid and a method to specify lift coefficient rather than angle-of-attack. A finite volume full potential multigrid method is used to model the outer inviscid flow field. First order viscous effects are modeled by a 3-D integral boundary layer method. Both turbulent and laminar boundary layers are treated. Wake thickness effects are modeled using a 2-D strip method. A brief discussion of the engineering aspects of the program is given. The input, output, and use of the program are covered in detail. Sample results are given showing the effects of boundary layer corrections and the capability of the lift specification method. Author

N89-20422# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
A CALCULATION METHOD FOR COMPRESSIBLE THREE DIMENSIONAL TURBULENT BOUNDARY LAYER FLOWS
L. J. JOHNSTON Jul. 1988 82 p
(VKI-TN-167; ETN-89-94121) Avail: NTIS HC A05/MF A01

A calculation method for compressible 3D boundary layers is described. The method involves a finite difference discretization of the governing mean flow equations. The differencing scheme used to discretize spanwise derivatives adapts automatically to the sign of the local crossflow within the boundary layer. A plane-by-plane solution procedure in the spanwise direction enables second-order accuracy to be maintained throughout the whole flow field. A normal coordinate scaling with the local total momentum thickness removes most of the boundary layer growth in computational space. The method is applied to a range of experimental flows, including compressible subsonic and supersonic free stream conditions. The Cebeci-Smith algebraic turbulence model is used for the initial validation of the calculation method. A simple modification to this model is tested, involving an explicit dependence of the outer eddy viscosity on the crossflow within the boundary layer. A significantly improved prediction of an infinite swept wing flow experiment is obtained. ESA

N89-20426# Calspan Corp., Buffalo, NY.
TRANSMISSION AND REFLECTION ON PRESSURE WAVES BY COMPRESSOR AND TURBINE STAGES, BASED ON AN ACTUATOR-DISK MODEL Technical Report, 1 Jun. 1986 - 1 Sep. 1987
W. J. RAE, P. F. BATCHO, and M. G. DUNN 1 Feb. 1988 49 p
(Contract DNA001-83-C-0182; DNA PROJ. N99-QMXA)
(AD-A203513; CALSPAN-7170-7; DNA-TR-88-58) Avail: NTIS HC A03/MF A01 CSCL 20D

The amplitudes of the pressure waves transmitted and reflected by an actuator disk due to the impingement of an incident pressure wave calculated. Analytic expressions for the wave amplitudes are derived for the limit where the incident pressure rise is small and these formulas, as well as direct calculations, are used to estimate the effect of multiple wave reflections from a pair of actuator disks. These predictions help to explain a number of phenomena that have been observed in measurements made when shock-tube generated overpressure waves were sent into an operating engine. GRA

N89-20468# Battelle Columbus Labs., OH.
DEVELOPMENT OF A ROTARY VALUE FOR PULSE COMBUSTION APPLICATIONS Final Report, Jun. 1986 - Mar. 1988
PAUL E. GEORGE and JOHN M. CORLISS 31 Oct. 1988 63 p
(Contract GRI-5086-234-1280)
(PB89-131114; GRI-88/0185) Avail: NTIS HC A04/MF A01 CSCL 13I

Research demonstrated the technical feasibility of a computer-controlled inlet-air rotary valve for pulse combustion applications. The results show that a Schimdt pulse combustor operated with a rotary valve provides similar performance in terms of heat transfer, pressure boost and turndown ratio to that of aero-valved and flapper-valved pulse combustors. The benefits of

scale-up ease, design flexibility and tolerance of adverse conditions do not justify the added cost of the valve, motor and control systems for most industrial applications. GRA

N89-20472*# Mechanical Technology, Inc., Latham, NY.
HIGH SPEED BALANCING APPLIED TO THE T700 ENGINE Final Report
J. WALTON, C. LEE, and M. MARTIN Mar. 1989 110 p Prepared in cooperation with Army Aviation Systems Command, Cleveland, OH
(Contract NAS3-23929; NAS3-24633; DA PROJ. 1L1-62209-AH-76)
(NASA-CR-180899; NAS 1.26:180899; MTI-87TR56; AVSCOM-TR-88-C-007) Avail: NTIS HC A06/MF A01 CSCL 13I

The work performed under Contracts NAS3-23929 and NAS3-24633 is presented. MTI evaluated the feasibility of high-speed balancing for both the T700 power turbine rotor and the compressor rotor. Modifications were designed for the existing Corpus Christi Army Depot (CCAD) T53/T55 high-speed balancing system for balancing T700 power turbine rotors. Tests conducted under these contracts included a high-speed balancing evaluation for T700 power turbines in the Army/NASA drivetrain facility at MTI. The high-speed balancing tests demonstrated the reduction of vibration amplitudes at operating speed for both low-speed balanced and non-low-speed balanced T700 power turbines. In addition, vibration data from acceptance tests of T53, T55, and T700 engines were analyzed and a vibration diagnostic procedure developed. Author

N89-20498# Air Force Systems Command, Wright-Patterson AFB, OH.
STRUCTURAL MECHANICS: CONTEMPORARY STATE AND PROSPECTS FOR DEVELOPMENT (SELECTED PORTIONS)
V. V. BOLOTIN, I. I. GOLDENBLAT, and A. F. SMIRNOV 19 Aug. 1988 83 p Transl. into ENGLISH from Stroitelnaya Mekhanika (Moscow, USSR), 1972 p 3, 65-98, 190-191
(AD-A198766; FTD-ID(RS)-T-0438-88) Avail: NTIS HC A05/MF A01 CSCL 20K

In recent years, many works have been published on structural mechanics and its application to calculation of structures, aircraft, ships and machines. However, among these investigations are still insufficient works of survey character, which give respresentation about the level of the interesting U.S. field of science as a whole. Survey/coverage in no way pretends to completeness; authors paid attention to those works which were close to their scientific interests. Examined in detail are sections dealing the theory of the elastoplastic calculation of constructions, statistical dynamics and the theory of the reliability of constructions, and mechanics of construction with the composite materials. A special chapter is dedicated to the application of electronic computers to structural mechanics. GRA

N89-20512*# Textron Bell Helicopter, Fort Worth, TX.
COUPLED ROTOR/FUSELAGE DYNAMIC ANALYSIS OF THE AH-1G HELICOPTER AND CORRELATION WITH FLIGHT VIBRATIONS DATA Final Report
J. C. CORRIGAN, J. D. CRONKHITE, R. V. DOMPKA, K. S. PERRY, J. P. ROGERS, and S. G. SADLER Jan. 1989 144 p
(Contract NAS1-17496)
(NASA-CR-181723; NAS 1.26:181723) Avail: NTIS HC A07/MF A01 CSCL 20K

Under a research program designated Design Analysis Methods for VIBrationS (DAMVIBS), existing analytical methods are used for calculating coupled rotor-fuselage vibrations of the AH-1G helicopter for correlation with flight test data from an AH-1G Operational Load Survey (OLS) test program. The analytical representation of the fuselage structure is based on a NASTRAN finite element model (FEM), which has been developed, extensively documented, and correlated with ground vibration test. One procedure that was used for predicting coupled rotor-fuselage vibrations using the advanced Rotorcraft Flight Simulation Program C81 and NASTRAN is summarized. Detailed descriptions of the analytical formulation of rotor dynamics equations, fuselage dynamic equations, coupling between the rotor and fuselage, and solutions to the total system of equations in C81 are included. Analytical predictions of hub shears for main rotor harmonics 2p, 4p, and 6p generated by C81 are used in conjunction with 2p OLS measured control loads and a 2p lateral tail rotor gearbox force, representing downwash impingement on the vertical fin, to excite the NASTRAN model. NASTRAN is then used to correlate with measured OLS flight test vibrations. Blade load comparisons predicted by C81 showed good agreement. In general, the fuselage vibration correlations show good agreement between anslysis and test in vibration response through 15 to 20 Hz. Author

N89-20519# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
BULGING CRACKS IN PRESSURIZED FUSELAGES: A NUMERICAL STUDY
E. RIKS 17 Nov. 1987 33 p
(Contract NIVR-06404N)
(NLR-MP-87058-U; ETN-89-94039) Avail: NTIS HC A03/MF A01

The possibility to obtain useful results by means of commercially available nonlinear finite element techniques in analyses of pressurized, stiffened, thin walled shells cylindrical shells was studied. Unstiffened as well as stiffened configurations based on actual fuselage designs were considered. It is shown that the nonlinear effect is large for large aspect ratios of the cracks and that stiffeners have, in general, a considerable effect on the stress intensity factors. ESA

N89-20520# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
ANALYSIS OF CRACK OPENING BEHAVIOR BY APPLICATION OF A DISCRETIZED STRIP YIELD MODEL
A. U. DEKONING and G. LIEFTING (Technische Hogeschool Twente, Enschede, Netherlands) 1 Mar. 1986 41 p Presented at the International Symposium on Fatigue Crack Closure, Charleston, WV, May 1986
(Contract NIVR-1823/01702-N)
(NLR-MP-87065-U; ETN-89-94043) Avail: NTIS HC A03/MF A01

The crack opening behavior of a fatigue crack in a centrally cracked panel was studied using a discretized version of the Dugdale and Barenblatt model. The effect of crack growth was also included. Results obtained for constant amplitude loading agree with data in the literature. The effect of application of single overload-underload combinations and of simple block loading programs on the crack opening behavior were analyzed. The results were compared with predictions based on an empirical model (CORPUS). The criteria used in the CORPUS model to select significant load excursions in the applied load sequence were checked. Both models were used to predict crack growth under a simplified landing gear load sequence. The predicted crack opening loads and the crack growth agree with experimental data. ESA

N89-20521# National Aerospace Lab., Amsterdam (Netherlands).
CURRENT STATUS OF FLIGHT SIMULATION FATIGUE CRACK GROWTH CONCEPTS
R. J. H. WANHILL and J. SCHIJVE 15 Jan. 1988 19 p Presented at the 3rd French Metallurgical Society International Spring Meeting, Paris, France, Jun. 1988
(NLR-MP-88001-U; ETN-89-94051) Avail: NTIS HC A03/MF A01

Crack growth models and methods of crack growth prediction are compared with respect to applicability and limitations. Research areas for improvement of crack growth prediction are specified. Fatigue crack growth predictions should be considered acceptable if within a factor of 2 of test results, and if they show the correct trends for variations of spectrum and test parameters. Although the choice of crack growth model depends on particular circumstances, it is preferable, certainly in the long term, to concentrate on improving and using crack opening models.

Improvement of crack opening models, in particular their ability to deal with plane strain/plane stress conditions and more complicated crack geometries, requires developments in analytical and experimental determinations of near-tip crack opening and the compilation of flight simulation fatigue test data banks. Usable models and methods for predicting short crack growth are years away. Their applicability will probably be restricted to damage tolerance of engine disks and blades and durability analysis of airframes. A better description of constant amplitude fatigue crack growth is needed, especially at low and high stress intensity levels and high stress ratios. More understanding is required of the interrelations between microstructure, fracture mechanisms, fracture topography, threshold, crack growth curve transition points, and crack opening behavior. ESA

N89-20525# Aeronautical Research Inst. of Sweden, Stockholm. Structures Dept.

ESTIMATION OF THE EQUIVALENT INITIAL FLOW SIZE (EIFS) DISTRIBUTION AND PREDICTION OF FAILURE PROBABILITIES FOR DIFFERENT PARAMETER VARIATIONS

LARS MORAEUS Oct. 1987 30 p Sponsored by the Swedish Board for Technical Development

(FFA-TN-1987-35; ETN-89-94123) Avail: NTIS HC A03/MF A01

The prediction of the probability of failure due to excessive cracking in aircraft structures was studied. Equivalent initial flaw size (EIFS) distribution for an aluminum alloy (2024-T3) was determined using experimental crack growth data for small cracks. The results show that the statistical basis for the EIFS determination must be considerably larger in order to draw any conclusions regarding the generic properties of the EIFS-distribution. Parameter influences on the probability of failure are investigated by using a hypothetical aircraft structure. Results show that the effect of varying the standard deviation of the extreme loads and the crack growth rate correlation time is almost negligible. ESA

N89-20950*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

THE 3-D EULER AND NAVIER-STOKES CALCULATIONS FOR AIRCRAFT COMPONENTS

VEER N. VATSA, BRUCE W. WEDAN, and ELI TURKEL (Institute for Computer Applications in Science and Engineering, Hampton, VA.) *In its* Transonic Symposium: Theory, Application, and Experiment, Volume 1, Part 2 p 571-579 Mar. 1989

Avail: NTIS HC A22/MF A01 CSCL 20D

An explicit multistage Runge-Kutta type of time-stepping scheme is used for solving transonic flow past a transport type wing/fuselage configuration. Solutions for both Euler and Navier-Stokes equations are obtained for quantitative assessment of boundary layer interaction effects. The viscous solutions are obtained on both a medium resolution grid of approximately 270,000 points and a find grid of 460,000 points to assess the effects of grid density on the solution. Computed pressure distributions are compared with the experimental data. Author

N89-21248# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

DEVELOPMENT OF A SHOCK CAPTURING CODE FOR USE AS A TOOL IN DESIGNING HIGH-WORK LOW ASPECT RATIO TURBINES M.S. Thesis

MARK A. DRIVER Dec. 1988 76 p

(AD-A202706; AFIT/GAE/AA/88D-10) Avail: NTIS HC A05/MF A01 CSCL 01A

A numerical algorithm is developed with the capability of capturing shocks in the internal blade passages of a modern gas turbine. The algorithm uses MacCormack's explicit finite difference scheme to solve the two-dimensional form of the Euler equations. Inlet and exit boundary conditions are developed that allow disturbances to propagate out of the computational domain without reflection. Periodic boundary conditions are applied such that an infinite cascade is modeled. The computed steady state solution is compared with experimental data for a high-work low aspect ratio turbine. The ability to obtain a reasonably accurate blade loading diagram within a practical execution time is demonstrated. Two oblique shocks, typical of those formed at the trailing edge of a transonic rotor blade, are captured. These shocks are smeared over several grid points, as expected with a shock capturing scheme, but their influence on the blade loading diagram is evident. GRA

N89-21270# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

APPLICATION OF THE BOUNDARY ELEMENT METHOD TO FATIGUE CRACK GROWTH ANALYSIS M.S. Thesis

TIMOTHY C. KELLEY Sep. 1988 142 p

(AD-A202565; AFIT/GAE/AA/88S-1) Avail: NTIS HC A07/MF A01 CSCL 20K

This investigation analyzes a crack emanating from one hole, and approaching a second hole, in a two hole tension strip with finite boundaries using the Boundary Element Method. The study included the effects of varying the hole diameter, hole separation and the length of the geometric correction factor beta, which can be presented as a family of curves. An example damage tolerance analysis is presented with the beta curves being incorporated into a beta look-up table as used in the NASA/FLAGRO fatigue crack growth program. This technique is acceptable in most fatigue crack growth programs now used in the aircraft industry to ensure aircraft structural integrity. Several classic fracture mechanics problems are analyzed, and computational efficiency as compared to conventional finite element techniques is investigated. Agreement with analytic solutions as well as other numerical methods (finite element) is excellent. The computation efficiency was shown to an improvement over existing methods. GRA

N89-21282# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.

MACROCRACK-MULTIPLE DEFECT INTERACTION CONSIDERING ELASTIC, PLASTIC AND VISCOPLASTIC EFFECTS M.S. Thesis

LEROY K. SMITH Dec. 1988 129 p

(AD-A203186; AFIT/GAE/AA/88D-35) Avail: NTIS HC A07/MF A01 CSCL 20K

A finite element investigation was conducted to analyze an axial tension specimen with collinear defects placed symmetrically about a center crack. The material modeled was IN-718, a nickel-based superalloy used in jet engines. The effects of crack/defect interaction were compared using elastic, elastic plastic, and viscoplastic constitutive models. A 2-D nonlinear finite element code called SNAP was used. This program has the capability to simulate crack growth and closure by releasing or closing nodes along the crack plane. Elastic stress intensity solutions were developed for two different finite width specimens. The stress intensity versus crack length plots compared well with infinite theory. Results show that the defect can partially shield the crack from finite width effects. A critical spacing was also noted where the stress intensity of the crack exceeded the stress intensity for the combined length of the crack and defect. The defect has a prominent influence range equal to approximately one defect length for all constitutive models. The presence of a defect increases the magnitude of the crack opening and stress/strain fields in front of the crack tip. GRA

N89-21759*# Auburn Univ., AL. Dept. of Algebra, Combinatorics and Analysis.

ROTORDYNAMIC ANALYSIS OF A BEARING TESTER

RICHARD A. ZALIK *In* Alabama Univ., Research Reports: 1988 NASA/ASEE Summer Faculty Fellowship Program 25 p Dec. 1988

Avail: NTIS HC A99/MF E03 CSCL 13I

The properties of the solutions of a system of four coupled nonlinear differential equations that model the behavior of the rotating shaft of a bearing tester are studied. In particular, it is shown how the bounds for the rotations of these equations can be obtained from bounds for the solutions of the linearized equations. By studying the behavior of the Fourier transforms of the solution, the approach to the stability boundary can also be

predicted. These conclusions are verified by means of numerical solutions of the equations, and of power spectrum density (PSD) plots. Author

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

A89-34028
A PHYSICAL-STATISTICAL METHOD FOR THE PREDICTION OF VERTICAL WIND SHEAR IN THE LOWER PART OF THE ATMOSPHERIC BOUNDARY LAYER [FIZIKO-STATISTICHESKII SPOSOB PROGNOZA VERTIKAL'NOGO SDVIGA VETRA V NIZHNEI CHASTI POGRANICHNOGO SLOIA ATMOSFERY]
T. V. DAVIDOVICH IN: Problems of weather forecasting and diagnostics. Moscow, Gidrometeoizdat, 1988, p. 31-41. In Russian. refs

A89-34359
WIND DAMAGE TO AIRPORTS - LESSONS LEARNED
HENRY LIU and FARIBORZ NATEGHI (Missouri-Columbia, University, Columbia) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 1, April 1988, p. 105-116. refs
(Contract NSF CEE-83-05014)

A postdisaster investigation of the June 17, 1985 windstorm-induced damage to the Columbia Regional Airport in Missouri reveals that the storm was a microburst, rather than a tornado as originally thought; the private-aircraft tiedown system was seriously flawed, and road-surfacing gravel was the primary source of damage to automobiles parked at the airport terminal. The gust factor of this type of wind event is much higher than normally assumed in structural design. The atmospheric pressure of the storm measured was greatly affected by the wind-generated pressure of the building in which the barometer was housed. The lessons to be learned from these data in engineering practice are discussed. O.C.

A89-34888#
THUNDERSTORM-GENERATED SOLITARY WAVES - A WIND SHEAR HAZARD
R. J. DOVIAK (NOAA, National Severe Storms Laboratory, Norman, OK) and D. R. CHRISTIE (Australian National University, Canberra, Australia) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 423-431. Previously cited in issue 07, p. 1060, Accession no. A88-22520. refs
(Contract DOT-FA01-80-Y-10524; AF-AFOSR-83-0045)

N89-20557# Federal Aviation Administration, Washington, DC. Office of Environment and Energy.
A MICROCOMPUTER POLLUTION MODEL FOR CIVILIAN AIRPORTS AND AIR FORCE BASES. MODEL APPLICATION AND BACKGROUND
H. M. SEGAL Aug. 1988 94 p Sponsored in part by AFESC, Tyndall AFB, FL
(AD-A199794; FAA-EE-88-5; AFESC/ESL-TR-88-55) Avail: NTIS HC A05/MF A01 CSCL 24A

This is the last of three reports describing the Emissions and Dispersion Modeling System (EDMS). It consists of an accumulation of five key documents describing the development and use of the EDMS model. This report is prepared in accordance with discussions with the EPA and requirements outlined in the March 27, 1980 Federal Register for submitting air quality models to the EPA. Model development and use, the influence of aircraft operations on air quality at airports, the Simplex A (a simplified atmospheric dispersion Model for airport use), microcomputer graphics in atmospheric dispersion modeling, and pollution from motor vehicles and aircraft at Stapleton International Airport are discussed. Atmospheric Dispersion Modeling; Pollution from Motor Vehicles and Aircraft at Stapleton International Airport (Abbreviated Report). (FR) GRA

N89-21417*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GAS TURBINE ALTERNATIVE FUELS COMBUSTION CHARACTERISTICS Final Report
R. JAMES ROLLBUHLER Feb. 1989 27 p
(Contract DE-AI01-85CE-50111)
(NASA-TM-101470; E-4584; DOE/NASA/50111-3; NAS 1.15:101470) Avail: NTIS HC A03/MF A01 CSCL 21D

An experimental investigation was conducted to obtain combustion performance and exhaust pollutant concentrations for specific synthetic hydrocarbon fuels. Baseline comparison fuels used were gasoline and diesel fuel number two. Testing was done over a range of fuel to air mass ratios, total mass flow rates, and input combustion air temperatures in a flame-tube-type gas turbine combustor. Test results were obtained in terms of released heat and combustion gas emission values. The results were comparable to those obtained with the base fuels with variations being obtained with changing operating conditions. The release of carbon particles during the tests was minimal. Author

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MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A89-33664
MULTISPECTRAL TERRAIN BACKGROUND SIMULATION TECHNIQUES FOR USE IN AIRBORNE SENSOR EVALUATION
MICHAEL WEINBERG, RONALD WOHLERS, JOHN CONANT, and EDWARD POWERS (Aerodyne Research, Inc., Billerica, MA) IN: Multispectral image processing and enhancement; Proceedings of the Meeting, Orlando, FL, Apr. 6-8, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 243-252.

A background simulation code called Aerie is discussed. Aerie is designed to reflect the major sources of IR background clutter that are of concern for the staring and scanning sensors being considered for various aircraft threat warning sensors. The Aerie characteristics are summarized, and the three-dimensional earth simulation procedures and the scene data base preparation Aerie uses are described. Some sample scenes generated by Aerie are shown. C.D.

A89-33751*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
A SMART PATTERN RECOGNITION SYSTEM FOR THE AUTOMATIC IDENTIFICATION OF AEROSPACE ACOUSTIC SOURCES
R. H. CABELL and C. R. FULLER (Virginia Polytechnic Institute and State University, Blacksburg) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 10 p. refs
(Contract NAG1-762)
(AIAA PAPER 89-1114)

An intelligent air-noise recognition system is described that uses pattern recognition techniques to distinguish noise signatures of five different types of acoustic sources, including jet planes, propeller planes, a helicopter, train, and wind turbine. Information for classification is calculated using the power spectral density and autocorrelation taken from the output of a single microphone. Using this system, as many as 90 percent of test recordings were

correctly identified, indicating that the linear discriminant functions developed can be used for aerospace source identification. I.S.

A89-33765*# Planning Research Corp., Hampton, VA.
PREDICTION OF FULL SYSTEM HELICOPTER NOISE FOR A MDHC 500E HELICOPTER USING THE ROTONET PROGRAM
D. S. WEIR, L. E. BECKER, and C. K. RUTLEDGE (Planning Research Corp., Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 16 p. refs
(Contract NAS1-18000)
(AIAA PAPER 89-1135)

The long-term goal of the NASA/U.S. helicopter industry program designated 'Rotonet' is the achievement of a helicopter noise signature-prediction capability on the basis of helicopter geometry and operating condition data. A prediction-validation data base is being compiled through flight testing of an MDHC 500E helicopter; the data base will encompass acoustic spectra, noise-level time histories, and effective perceived noise levels incorporating actual meteorological conditions and helicopter dynamics. An evaluation is made of the Rotonet system as currently defined, with a view to prospective developments. O.C.

A89-34132
STABILITY ANALYSIS OF THE MULTIPLE DISCRETE STABILIZATION SYSTEM OF AN ELASTIC FLIGHT VEHICLE [ANALIZ USTOICHIVOSTI MNOGOKRATNOI DISKRETNOI SISTEMY STABILIZATSII UPRUGOGO LETATEL'NOGO APPARATA]
E. I. SOMOV and E. A. BONDARENKO Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1988, p. 26-30. In Russian. refs

A mathematical model is presented which describes, in state space, a linear discrete flight vehicle stabilization system of the multiple type with delay. The approach proposed here has been used to analyze the stability of the closed-loop linear continuous/discrete gyroscopic stabilization system of a large flight vehicle in the case of the practically complete absence of the natural damping of elastic vibrations of the structure. V.L.

A89-34569* Virginia Polytechnic Inst. and State Univ., Blacksburg.
EFFICIENT OPTIMIZATION OF INTEGRATED AERODYNAMIC-STRUCTURAL DESIGN
R. T. HAFTKA, B. GROSSMAN, W. M. EPPARD, P. J. KAO, and D. M. POLEN (Virginia Polytechnic Institute and State University, Blacksburg) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 28, March 1989, p. 593-607. refs
(Contract NAG1-505; NAG1-603)

Techniques for reducing the computational complexity of multidisciplinary design optimization (DO) of aerodynamic structures are described and demonstrated. The basic principles of aerodynamic and structural DO are reviewed; the formulation of the combined DO problem is outlined; and particular attention is given to (1) the application of perturbation methods to cross-sensitivity computations and (2) numerical approximation procedures. Trial DOs of a simple sailplane design are presented in tables and graphs and discussed in detail. The IBM 3090 CPU time for the entire integrated DO was reduced from an estimated 10 h to about 6 min. T.K.

A89-34900#
FINITE-SURFACE SPLINE
KARI APPA (Northrop Corp., Aircraft Div., Hawthorne, CA) Journal of Aircraft (ISSN 0021-8669), vol. 26, May 1989, p. 495, 496. refs

The present method employs uniform plate elements to represent a given platform by means of a number of quadrilateral or triangular bending elements. A set of constraint conditions using shape functions that are employed in the determination of the stiffness matrix of the plate element are established, in such a way that the deformed plate passes through the given data points. Subsequently, a mapping matrix relating displacements at structural and aerodynamic grid points are derived; the transformation matrix furnishes a general two-dimensional interpolation scheme that is also applicable to pressure, temperature, or strains. O.C.

A89-35044*# Pennsylvania State Univ., University Park.
OBSERVER DESIGN FOR COMPENSATION OF NETWORK-INDUCED DELAYS IN INTEGRATED COMMUNICATION AND CONTROL SYSTEMS
R. LUCK and A. RAY (Pennsylvania State University, University Park) IN: Recent advances in control of nonlinear and distributed parameter systems, robust control, and aerospace control applications; Proceedings of the Symposium, ASME Winter Annual Meeting, Chicago, IL, Nov. 27-Dec. 2, 1988. New York, American Society of Mechanical Engineers, 1988, p. 175-182. refs
(Contract NAG3-823; NSF DMC-87-07648)

A method for compensating the effects of network-induced delays in integrated communication and control systems (ICCS) is proposed, and a finite-dimensional time-invariant ICCS model is developed. The problem of analyzing systems with time-varying and stochastic delays is circumvented by the application of a deterministic observer. For the case of controller-to-actuator delays, the observed design must rely on an extended model which represents the delays as additional states. R.R.

A89-35261
FREQUENCY DOMAIN TECHNIQUES APPLIED TO THE IDENTIFICATION OF HELICOPTER DYNAMICS
P. YOUNG and R. J. PATTON (York, University, England) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 153-158. Research supported by SERC and Royal Aircraft Establishment. refs

The application of frequency domain techniques to the identification of helicopter dynamics using a scale-model helicopter as a test system is described. Simulations of the helicopter using linear models of longitudinal and lateral motion are detailed. A comparison is made between the performances of two input signals in identifying the transfer functions of the models. K.K.

A89-35283
QUANTITATIVE DESIGN FOR SYSTEMS WITH UNCERTAINTY AND CONTROL FAILURES
I. HOROWITZ, S. WANG (California, University, Davis), and C. HOUPIS (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: International Conference on Control 88, Oxford, England, Apr. 13-15, 1988, Proceedings. London, Institution of Electrical Engineers, 1988, p. 547-552. refs
(Contract NSF ECS-86-08875)

The application of quantitative feedback theory (QFT) to flight control systems in which the uncertainty consists of varying flight conditions and possible failures of effectors is discussed. The design procedure is discussed as well as application to flight control with effector failures. It was possible to obtain highly satisfactory designs because of the simple, direct, logical, and transparent nature of QFT MIMO design. K.K.

N89-20683*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
RELIABILITY AND PERFORMANCE EVALUATION OF SYSTEMS CONTAINING EMBEDDED RULE-BASED EXPERT SYSTEMS Final Report
ROBERT M. BEATON, MILTON B. ADAMS, and JAMES V. A. HARRISON Feb. 1989 35 p
(Contract NAS9-17560)
(NASA-CR-181769; NAS 1.26:181769) Avail: NTIS HC A03/MF A01 CSCL 09B

A method for evaluating the reliability of real-time systems containing embedded rule-based expert systems is proposed and investigated. It is a three stage technique that addresses the impact of knowledge-base uncertainties on the performance of expert systems. In the first stage, a Markov reliability model of the system is developed which identifies the key performance parameters of the expert system. In the second stage, the evaluation method is used to determine the values of the expert system's key

performance parameters. The performance parameters can be evaluated directly by using a probabilistic model of uncertainties in the knowledge-base or by using sensitivity analyses. In the third and final state, the performance parameters of the expert system are combined with performance parameters for other system components and subsystems to evaluate the reliability and performance of the complete system. The evaluation method is demonstrated in the context of a simple expert system used to supervise the performances of an FDI algorithm associated with an aircraft longitudinal flight-control system. Author

N89-21592# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
SELECTION OF A FREQUENCY SENSITIVE QFT (QUANTITATIVE FEEDBACK THEORY) WEIGHTING MATRIX USING THE METHOD OF SPECIFIED OUTPUTS M.S. Thesis
WILLIAM D. PHILLIPS Dec. 1988 112 p
(AD-A202692; AFIT/GAE/ENG/88D-01) Avail: NTIS HC A06/MF A01 CSCL 01D

Use of Quantitative Feedback Theory (QFT) on a multiple input multiple output control system requires certain mathematical properties of the plant matrix of transfer functions. In general, the plant matrix P(s) does not possess the necessary or desired mathematical properties for the QFT design to proceed. A frequency sensitive weighting matrix Delta(s) is used to transform the plant matrix P(s) into the equivalent plant matrix Pe(s) that does satisfy QFT requirements. In matrix notation, the relationship between the equivalent plant, plant, and weighting matrix is Pe(s)=P(s) Delta(s). This thesis identifies the necessary and desired characteristics of the equivalent plant Pe(s) for the QFT process, explains the use of the Method of Specified Outputs which generates the frequency sensitive weighting matrix Delta(s), and calculates several weighting matrices for a 3-input 2-output lateral-directional model of the F-16 aircraft. For several control system failures, the mathematical structure of the failed equivalent plant matrices Pef(s) is examined for compliance with QFT requirements. A weighting matrix Delta(s) is found that produces acceptable equivalent plant matrices for failures of down to 0.01 percent of available control surface deflections. GRA

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PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A89-33708*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NOISE REDUCTION OF A COMPOSITE CYLINDER SUBJECTED TO RANDOM ACOUSTIC EXCITATION
FERDINAND W. GROSVELD and T. BEYER (NASA, Langley Research Center; Planning Research Corp., Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(Contract NAS1-18000)
(AIAA PAPER 89-1049)

Interior and exterior noise measurements were conducted on a stiffened composite floor-equipped cylinder, with and without an interior trim installed. Noise reduction was obtained for the case of random acoustic excitation in a diffuse field; the frequency range of interest was 100-800-Hz one-third octave bands. The measured data were compared with noise reduction predictions from the Propeller Aircraft Interior Noise (PAIN) program and from a statistical energy analysis. Structural model parameters were not predicted well by the PAIN program for the given input parameters; this resulted in incorrect noise reduction predictions for the lower one-third octave bands where the power flow into the interior of the cylinder was predicted on a mode-per-mode basis. B.J.

A89-33712#
ACOUSTIC FORCING OF THREE DIMENSIONAL SHEAR LAYERS
MARTIN V. LOWSON (Bristol, University, England) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 13 p. refs
(AIAA PAPER 89-1063)

The response to acoustic forcing of the separated vortex flow over delta wings at low speeds has been experimentally investigated in the 5000-50,000 Reynolds number range. Two distinct modes of instability were found for the shear layer, one analagous to the classic Kelvin-Helmholtz response of the two-dimensional shear layer, and the other a streamwise instability which may correspond to the theory of Lin and Corcos (1984). At sufficiently high sound levels, the flow was shown to be entirely disrupted. R.R.

A89-33715*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIRFOIL PROFILE DRAG INCREASE DUE TO ACOUSTIC EXCITATION
JOHN G. SHEARIN (NASA, Langley Research Center, Hampton, VA) and MICHAEL G. JONES (Planning Research Corp., Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 7 p. refs
(AIAA PAPER 89-1069)

A two-dimensional airfoil (NACA-0009) is subjected to high intensity pure-tone sound over a 1-5 kHz frequency range while immersed in a flow with 240 ft/sec velocity in a quiet flow facility with a Reynolds number of 3 million. Wake dynamic pressures are determined, and the momentum deficit is used to calculate a two-dimensional drag coefficient. Significant increases in drag are observed when the airfoil is subjected to high-intensity sound at critical frequencies. The increased drag is accompanied by movement of the natural transition location. When the transition is fixed by roughness at 10 percent chord, no further transition movement is observed in response to an acoustic Tollmien-Schlichting disturbance. However, a 4 percent increase in the sectional drag coefficient is noted. It is believed to be due to the sound exciting the flow near the airfoil surface (shear layer), thus causing the existing turbulence to become more intense, possess a higher mixing rate (momentum), and increase the skin friction. S.A.V.

A89-33716#
ON SOUND GENERATION BY A JET FLOW PASSING A SEMI-INFINITE AEROFOIL
Y. P. GUO (Cambridge University, England) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 11 p. refs
(AIAA PAPER 89-1070)

This paper studies the sound generated when a steadily convected jet flow impinges upon a fixed semi-infinite aerofoil. Far field sound pressures and the unsteady load experienced by the aerofoil are analytically examined for both subsonic and supersonic mean flows. Energetics is considered according to definitions usually used in acoustics of moving flows. Author

A89-33722*# Joint Inst. for Advancement of Flight Sciences, Hampton, VA.
ASYMPTOTIC/NUMERICAL ANALYSIS OF SUPERSONIC PROPELLER NOISE
M. K. MYERS and R. WYDEVEN (Joint Institute for Advancement of Flight Sciences, Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 11 p. refs
(Contract NCC1-14)
(AIAA PAPER 89-1078)

An asymptotic analysis based on the Mach surface structure of the field of a supersonic helical source distribution is applied to predict thickness and loading noise radiated by high speed propeller blades. The theory utilizes an integral representation of the

Ffowcs-Williams Hawkings equation in a fully linearized form. The asymptotic results are used for chordwise strips of the blade, while required spanwise integrations are performed numerically. The form of the analysis enables predicted waveforms to be interpreted in terms of Mach surface propagation. A computer code developed to implement the theory is described and found to yield results in close agreement with more exact computations. Author

A89-33723#
A LIFTING LINE MODEL FOR PROPELLER NOISE
H. H. BROUWER (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 9 p. refs
(AIAA PAPER 89-1079)

The possibility of calculating the sound field of a propeller from knowledge of the spanwise lift distribution, is investigated. An expression for the sound pressure is derived within a first-order approximation for blades of high aspect ratio. In this approximation the propeller is described by a system of rotating lifting lines. Numerical results for a six-bladed model propeller are compared with experimental data and the results of a theory based on a detailed description of the propeller geometry. It appears that for a high-aspect-ratio propeller, the agreement is satisfactory. Author

A89-33724*# United Technologies Corp., Windsor Locks, CT.
SOUND POWER SPECTRUM AND WAVE DRAG OF A PROPELLER IN FLIGHT
D. B. HANSON (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 17 p. Research supported by United Technologies Corp. refs
(Contract NAS3-23720)
(AIAA PAPER 89-1081)

Theory is presented for the sound power and sound power spectrum of a single rotation propeller in forward flight. Calculations are based on the linear wave equation with sources distributed over helicoidal surfaces to represent effects of blade thickness and steady loading. Sound power is distributed continuously over frequecy, as would be expected from Doppler effects, rather than in discrete harmonics. The theory is applied to study effects of sweep and Mach number in propfans. An acoustic efficiency is defined as the ratio of radiated sound power to shaft input power. This value is the linear estimate of the effect of wave drag due to the supersonic blade section speeds. It is shown that the acoustic efficiency is somewhat less than 1 percent for a well designed propfan. Author

A89-33726#
FINITE ELEMENT MODELLING OF SHEARED FLOW EFFECTS ON THE RADIATION CHARACTERISTICS OF ACOUSTIC SOURCES IN A CIRCULAR DUCT
JAMES EDWARD STECK and WALTER EVERSMAN (Missouri-Rolla, University, Rolla) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(AIAA PAPER 89-1085)

A mixed finite element method is proposed for solving a third-order partial differential equation governing the acoustic pressure field in a duct containing radially sheared subsonic flow. The approach used here is to treat this equation as a coupled pair of differential equations, one a second-order equation in terms of acoustic density and the other a first-order equation in terms of an artificial variable representing the effects of the sheared flow. The finite element code is refined using numerical experiments, and results are presented for a specific propeller and duct geometry. V.L.

A89-33729*# Florida State Univ., Tallahassee.
FORWARD FLIGHT EFFECTS ON BROADBAND SHOCK ASSOCIATED NOISE OF SUPERSONIC JETS
CHRISTOPHER K. W. TAM (Florida State University, Tallahassee) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 16 p. refs
(Contract NAG1-421)
(AIAA PAPER 89-1088)

The stochastic model theory of TAM (1987, 1989) for broadband shock associated noise was extended to include the effects of forward flight. The theory was applied to the forward flight simulation experiments of Norum and Shearin (1984, 1986, and 1988). Good agreement is found between calculated and measured far-field noise spectra over the flight Mach number range of 0.0 to 0.4. K.K.

A89-33733#
INTERACTION NOISE MECHANISMS FOR AN ADVANCED PROPELLER - EXPERIMENTAL RESULTS
J. C. SIMONICH, D. C. MCCORMICK, and P. L. LAVRICH (United Technologies Research Center, East Hartford, CT) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 16 p. Research supported by United Technologies Corp. refs
(AIAA PAPER 89-1093)

The interaction mechanisms associated with wakes incident upon rotating propfan blades are presently studied experimentally in order to generate a database for the improvement of noise-prediction methodology components and achieve a deeper understanding of interaction-noise generation. A single, stationary, swept fan blade representative of a state-of-the-art profan was used to generate a wake upstream of a single-rotating propfan and gather interaction noise measurements. A potentially dominant interaction noise-source mechanism, related to a velocity defect associated with the leading edge vortex of the swept blade, was identified. This vortex defect/blade interaction generated significant blade surface pressure fluctuations. O.C.

A89-33734#
INTERACTION NOISE MECHANISMS FOR ADVANCED PROPELLERS - ANALYTICAL EVALUATION
D. J. PARZYCH (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) and P. L. LAVRICH (United Technologies Research Center, East Hartford, CT) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 8 p.
(AIAA PAPER 89-1094)

Theoretical lift response and unsteady noise radiation models were evaluated by comparing predictions with test results of a model three bladed Prop-Fan located downstream of stationary swept and unswept vanes. The wakes shed by the upstream vane were measured and used as input to the theories, therefore eliminating the ambiguity of unsteady air angles at the downstream rotor. The vane wake interaction noise was isolated by subtracting the measured rotor-alone noise from the measured total noise. It was found that the lift response and noise radiation model evaluated showed good agreement with the measured results. Author

A89-33736#
NEAR-FIELD NOISE OF A PUSHER PROPELLER
P. L. SPENCE, M. B. TRACY, and M. A. TAKALLU (Planning Research Corp., Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 13 p. refs
(AIAA PAPER 89-1096)

A theoretical/computational code is used to predict the near field noise generated by a propeller in a pusher configuration. The wake due to the pylon upstream of the propeller is generated using a similarity formulation. Unsteady loads on the propeller are determined by implementing a time-dependent variation of the sectional angles of attack and Mach numbers along with the periodic circulation due to shed vortices from the propeller's trailing edge. Using this unsteady loading, noise predictions are performed and compared, along with steady loading noise predictions, to existing flight test measurements. The measured data were obtained from earlier flight tests of a general aviation aircraft with engines installed in pusher configurations. The predicted results show that the unsteady loading effects are more pronounced out of the plane of the propeller disk. The steady loading is not sufficient

to account for the level of measured data and the unsteady loading noise must be included in the prediction. Author

A89-33737*# Missouri Univ., Rolla.
THE EFFECT OF THE WIND TUNNEL WALL BOUNDARY LAYER ON THE ACOUSTIC TESTING OF PROPELLERS
WALTER EVERSMAN (Missouri-Rolla, University, Rolla) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 10 p. Research supported by NASA. refs
(AIAA PAPER 89-1097)

An approximation based on the representation of the boundary layer by lamina of uniform flow with suitable interlayer boundary conditions is shown to be accurate, efficient, and compatible with finite element formulations. The approximation has been implemented using existing codes to produce a model for assessing the suitability of the acoustic environment in a wind tunnel for the acoustic testing of propellers. It is found that, with suitable acoustic treatment and with measurements made near the propeller and well removed from the walls, the free field directivity and level can be reproduced with good fidelity. V.L.

A89-33738#
FUSELAGE BOUNDARY LAYER EFFECTS ON SOUND PROPAGATION AND SCATTERING
H. Y. LU (Boeing Commercial Airplanes, Seattle, WA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 10 p. refs
(AIAA PAPER 89-1098)

The effects of a fuselage and its boundary layer on sound propagation to the fuselage surface and on sound scattering in the farfield were analyzed. A hard-wall infinite cylinder with a boundary layer of both velocity and temperature variations was modeled to simulate the fuselage of an aircraft in flight. Examples for a monopole noise source outside the boundary layer showed considerable noise attenuation on the cylindrical surface forward of the source and much less effect on the downstream side. Data from a transonic wind tunnel test showed the same trends. For enroute and airport community noise, the boundary layer alters the interference pattern caused by the fuselage. Author

A89-33759#
EXPERIMENTAL INVESTIGATION OF ROTOR WAKE/STATOR INTERACTION NOISE GENERATION BY ACOUSTIC MODE MEASUREMENTS
T. ZANDBERGEN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 10 p. Research supported by the Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs
(AIAA PAPER 89-1126)

The rotor wake/stator interaction noise generation was investigated using acoustic measurements in a low-speed wind tunnel, downstream of a rotor/stator combination; some acoustic measurements were also carried out in the intake duct of the wind tunnel model and outside the model. The blade passing frequency harmonics were found to be dominated by the regular rotor/stator interaction modes. In addition, cut-off rotor/stator interaction modes were observed; the origin of these is considered to be in the highly nonuniform flow downstream of the rotor/stator. An additinal noise source occurred due to the lock-in of rotor vortex shedding and acoustic spinning modes. I.S.

A89-33761*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCED TURBOPROP AIRCRAFT FLYOVER NOISE ANNOYANCE - COMPARISON OF DIFFERENT PROPELLER CONFIGURATIONS
DAVID A. MCCURDY (NASA, Langley Research Center, Hampton, VA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(AIAA PAPER 89-1128)

A laboratory experiment was conducted to compare the annoyance of flyover noise from advanced turboprop aircraft having different propeller configurations with the annoyance of conventional turboprop and jet aircraft flyover noise. It was found that advanced turboprops with single-rotating propellers were, on average, slightly less annoying than the other aircraft. Fundamental frequency and tone-to-broadband noise ratio affected annoyance response to advanced turboprops but the effects varied with propeller configuration and noise metric. The addition of duration corrections and corrections for tones above 500 Hz to the noise measurement procedures improved prediction ability. Author

A89-33762#
AN ANALYTICAL MODEL FOR THE PREDICTION OF MR/TR INTERACTION NOISE
HORMOZ TADGHIGHI (McDonnell Douglas Helicopter Co., Mesa, AZ) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 15 p. refs
(AIAA PAPER 89-1130)

A detailed analytical study of helicopter tail rotor (TR) noise due to interactions with the main rotor (MR) tip vortices is presented. The airloads due to MR/TR vortex interaction are modeled assuming an airfoil of infinite span cutting through a moving vortex. The investigation included the use of rotor free wake analysis to accurately define the geometry of the interacting discrete tip vortices from the main rotor. A comparison of the airloads and acoustic predictions with measurements is given. In particular, the predictions of waveform features and peak amplitude for the interactions inboard of the blade tip compared favorably with measured data. B.J.

A89-33763#
INTEGRATING THE ACOUSTIC ANALOGY FOR SUPERSONIC ROTATING SURFACES
VALANA L. WELLS (Arizona State University, Tempe) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 16 p. refs
(AIAA PAPER 89-1133)

This paper discusses the analytical characteristics of waveforms produced by rotating surface sources with tip Mach number greather than 1. The analysis covers both monopole and quadrupole sources which have the greatest importance for prediction of high-speed rotor noise. By using idealized source distributions over the rectangular surfaces, the results show that the Lighthill/Curle analogy with time derivatives taken outside the integrals poses no additional difficulty attributable to numerical error. Author

A89-33764*# Florida Atlantic Univ., Boca Raton.
THE PREDICTION OF BLADE WAKE INTERACTION NOISE BASED ON A TURBULENT VORTEX MODEL
STEWART A. L. GLEGG (Florida Atlantic University, Boca Raton) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 9 p. refs
(Contract NAG1-715)
(AIAA PAPER 89-1134)

Blade wake interaction is defined as the broadband noise generated by the interaction of helicopter rotor blades with their own wake. Experimental observations have shown that this is a strong function of advance ratio and tip path plane angle. This paper describes how this noise source can be associated with the blade vortex interactions in the forward sector of the rotor. Measured levels of turbulence in the vortex core are used to predict the broadband noise levels with some success. However, more detailed information on the turbulence spectrum and the trajectory of the shed vortices is required before more accurate noise predictions can be made. Author

A89-33766#
NOISE AND INSTABILITY WAVES IN SUPERSONIC JETS IN THE PROXIMITY OF FLAT AND CYLINDRICAL WALLS
K. K. AHUJA, J. A. MCCAULLEY, and C. K. W. TAM (Lockheed Aeronautical Systems Co., Marietta, GA) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p.

Research supported by Lockheed Internal Research and Development Program. refs
(AIAA PAPER 89-1136)

The effect of the proximity of fuselage on the noise radiated from a model supersonic unheated round jet exhausting parallel to the fuselage wall was investigated using acoustic measurements, complemented by phase-locked measurements of the instability waves in the jet, in a flow visualization facility. Results showed that, as the jet is brought close to the fuselage surface, drastic changes in the noise occur only after the nozzle to fuselage distance becomes about one jet exit diameter or less. The effect of the fuselage curvature (investigated using a flat and a cylindrical fuselage) on the radiated noise was found to be insignificant. I.S.

A89-33768#
TWIN-JET SCREECH SUPPRESSION
L. L. SHAW (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(AIAA PAPER 89-1140)

Results are reported from an experimental investigation of screech noise in twin jet-engine configurations and of methods for suppressing this noise. The acoustic mechanisms of screech generation and amplification are reviewed; the experimental setup (in which acoustic and phase-averaged schlieren data are obtained on a 4.7-percent scale model of an F-15 aircraft equipped with axisymmetric nozzles) is described; and the results are presented in extensive graphs and flow visualizations. Screech tones with amplitudes up to 163 dB are measured, with amplification by up to 20 dB due to interplume coupling. Suppression by active noise cancellation and by shifting the nozzle exit planes is found to be ineffective; small tabs mounted in the exit plane are very effective in suppressing screech from both single and twin jets, while a small secondary jet is effective for single-jet screech. T.K.

A89-33770#
HUB TO TIP VARIATIONS OF COUNTER ROTATING PROPELLER INTERACTION NOISE
H. V. L. PATRICK (Tennessee, University, Knoxville) and R. T. NAGEL (North Carolina State University, Raleigh) AIAA, Aeroacoustics Conference, 12th, San Antonio, TX, Apr. 10-12, 1989. 12 p. refs
(AIAA PAPER 89-1145)

Axial and circumferential flow velocity components were measured at discretepoints between hobby-craft model counter-rotating propellers using a single sensor hot-film anemometer. Coherence analysis was used to determine characteristics of the relationship between the far-field radiated noise and the measured flow velocity components at the primary aerodynamics interaction tones. Tests were performed in an open-jet anechoic wind tunnel at a free-stream speed of 0.08 Mach number with a 3 x 4 CRP configuration. It was determined that the degree of linearity in the flow-noise relation varied radially along the propeller blade span. Author

A89-35385
PREDICTION OF POTENTIAL NOISE INTERACTIONS IN AXIAL-FLOW MACHINES - APPLICATION TO THE HELICOPTER FENESTRON [PREDICTION DU BRUIT D'INTERACTIONS POTENTIELLES DANS LES MACHINES TOURNANTES - APPLICATION AU FENESTRON D'HELICOPTERE]
FRANCETTE FOURNIER and MICHEL ROGER (Lyon, Ecole Centrale, Ecully, France) Academie des Sciences (Paris), Comptes Rendus, Serie II - Mecanique, Physique, Chimie, Sciences de l'Univers, Sciences de la Terre (ISSN 0249-6305), vol. 308, no. 8, Feb. 23, 1989, p. 703-706. In French.

A method for predicting the far-field noise created in a rotor by the flow around cylindrical obstacles (such as support arms) placed downstream of the rotor is proposed. Application of the method to helicopter rotor blades shows that this noise source can account for the fundamental and first harmonics of the blade frequencies. It is suggested that higher frequences may be due to the absorption of atmospheric turbulence. R.R.

A89-35388
PREDICTION OF WAKE-INTERACTION NOISE IN AXIAL-FLOW MACHINES - APPLICATION TO HELICOPTER FENESTRON [PREDICTION DU BRUIT D'INTERACTION DE SILLAGES DANS LES MACHINES TOURNANTES - APPLICATION AU FENESTRON D'HELICOPTERE]
FRANCETTE FOURNIER and MICHEL ROGER (Lyon, Ecole Centrale, Ecully, France) Academie des Sciences (Paris), Comptes Rendus, Serie II - Mecanique, Physique, Chimie, Sciences de l'Univers, Sciences de la Terre (ISSN 0249-6305), vol. 308, no. 9, March 2, 1989, p. 831-834. In French. refs

A wake model based on experimental measurements is used to determine the noise generated by rotor-stator interactions in an axial-flow machine. Application of the model to the tail rotor of a helicopter shows that the 3rd to 9th harmonics of the blade passing frequency can be attributed to this noise source. Neither the first two harmonics nor the large-band noise are attributed to wake interactions. R.R.

N89-20776*# Sverdrup Technology, Inc., Cleveland, OH.
NOISE GENERATED BY A FLIGHT WEIGHT, AIR FLOW CONTROL VALVE IN A VERTICAL TAKEOFF AND LANDING AIRCRAFT THRUST VECTORING SYSTEM Final Report
RONALD G. HUFF Feb. 1989 55 p Prepared in cooperation with Huff (Ronald G.) and Associates, North Olmsted, OH
(Contract NAS3-25266)
(NASA-CR-182232; E-4556; NAS 1.16:182232) Avail: NTIS HC A04/MF A01 CSCL 20A

Tests were conducted in the NASA Lewis Research Center's Powered Lift Facility to experimentally evaluate the noise generated by a flight weight, 12 in. butterfly valve installed in a proposed vertical takeoff and landing thrust vectoring system. Fluctuating pressure measurements were made in the circular duct upstream and downstream of the valve. This data report presents the results of these tests. The maximum overall sound pressure level is generated in the duct downstream of the valve and reached a value of 180 dB at a valve pressure ratio of 2.8. At the higher valve pressure ratios the spectra downstream of the valve is broad banded with its maximum at 1000 Hz. Author

N89-20777*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACOUSTIC TEST OF A MODEL ROTOR AND TAIL ROTOR: RESULTS FOR THE ISOLATED ROTORS AND COMBINED CONFIGURATION
R. M. MARTIN, C. L. BURLEY, and J. W. ELLIOTT Feb. 1989 73 p
(NASA-TM-101550; NAS 1.15:101550) Avail: NTIS HC A04/MF A01 CSCL 20A

Acoustic data from a model scale main rotor and tail rotor experiment in the NASA Langley 14 by 22 Foot Subsonic Tunnel are presented for the main rotor and trail rotor in isolation and for the two rotors operating together. Results for the isolated main rotor show the importance of the rotor flapping conditions on mid-frequency noise content. High levels of main rotor retreating side blade-vortex interaction noise are shown to radiate downstream of the model. The isolated tail rotor noise results show the dominance of harmonic noise in the thrusting direction. The occurrence of tail rotor broadband noise is seen by the broadening of the tail rotor harmonics and is attributed to fuselage wake turbulence. The combined main and tail rotor data are presented to show the dominance of each rotor's different noise sources at different directivity locations. Author

N89-20779*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UNSTEADY BLADE PRESSURE MEASUREMENTS ON A MODEL COUNTERROTATION PROPELLER
LAURENCE J. HEIDELBERG and RICHARD P. WOODWARD Apr.

1989 22 p Presented at the 12th Aerocoustics Conference, San Antonio, TX, 10-12 Apr. 1989; sponsored inpart by AIAA
(NASA-TM-102002; E-4684; NAS 1.15:102002; AIAA-89-1144)
Avail: NTIS HC A03/MF A01 CSCL 20A

In an exploratory effort an advanced counterrotation propeller instrumented with blade-mounted pressure transducers was tested in the NASA Lewis 9- by 15-Foot Anechoic Wind Tunnel at a simulated takeoff and landing speed of Mach 0.20. The propeller's aft diameter was reduced to investigate possible noise reductions resulting from reduced blade row interaction with the tip vortex. The propeller was tested at three blade row spacings at fixed blade setting angles, at themaximum blade row spacing at higher blade setting angles and at propeller axis angles attack to the flow up to + or - 16 deg. A limited number of unsteady blade surface pressure measurements were made on both rotors of the model counterrotation propeller. Emphasis was placed on determining the effects of rotor-rotor interactions on the blade surface pressures. A unique method of processing the pressure signals was developed that enables even weak interaction waveforms and spectra to be separated from the total signal. The interaction on the aft rotor was many times stronger than thaton the forward rotor. The fundamental rotor interaction tone exhibited complicated behavior but generally increased with rotational speed and blade setting angle and decreased with rotor spacing. With the propeller axis at an angle to the flow, the phase response of the aft rotor appeared to be significantly affected by the presence of the forward rotor. Author

N89-21628*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

COMPARISON OF PROPELLER CRUISE NOISE DATA TAKEN IN THE NASA LEWIS 8- BY 6-FOOT WIND TUNNEL WITH OTHER TUNNEL AND FLIGHT DATA

JAMES H. DITTMAR Apr. 1989 23 p Presented at the 12th Aeroacoustics Conference, San Antonio, TX, 10-12 Apr. 1989; sponsored in part by AIAA
(NASA-TM-101976; E-4676; NAS 1.15:101976; AIAA-89-1059)
Avail: NTIS HC A03/MF A01 CSCL 20A

The noise of advanced high speed propeller models measured in the NASA 8- by 6-foot wind tunnel has been compared with model propeller noise measured in another tunnel and with full-scale propeller noise measured in flight. Good agreement was obtained for the noise of a model counterrotation propeller tested in the 8- by 6-foot wind tunnel and in the acoustically treated test section of the Boeing Transonic Wind Tunnel. This good agreement indicates the relative validity of taking cruise noise data on a plate in the 8- by 6-foot wind tunnel compared with the free-field method in the Boeing tunnel. Good agreement was also obtained for both single rotation and counter-rotation model noise comparisons with full-scale propeller noise in flight. The good scale model to full-scale comparisons indicate both the validity of the 8- by 6-foot wind tunnel data and the ability to scale to full size. Boundary layer refraction on the plate provides a limitation to the measurement of forward arc noise in the 8- by 6-foot wind tunnel at the higher harmonics of the blade passing tone. The use of a validated boundary layer refraction model to adjust the data could remove this limitation. Author

N89-21632# Army Construction Engineering Research Lab., Champaign, IL.

ATTENUATION OF BLAST WAVES USING FOAM AND OTHER MATERIALS Final Report

RICHARD RASPET, S. K. GRIFFITHS, JOSEPH M. POWERS, HERMAN KRIER, and TIMOTHY D. PANCZAK Nov. 1988 72 p
(AD-A203148; CERL-TM-N-89/01) Avail: NTIS HC A04/MF A01 CSCL 19I

Noise is a problem everywhere the Army trains or tests with large weapons or helicopters. Noise and hazardous waste have been listed as the major problems facing the Army into the 21st century. Research at the U.S. Army Construction Engineering Research Laboratory (USA-CERL) is aimed at solving the total noise problem for the Army. This report documents several years of fundamental research into methods to quiet explosive noise and materials used to reduce the noise from explosions. This report reproduces journal articles regarding this USA-CERL research in chronological order. GRA

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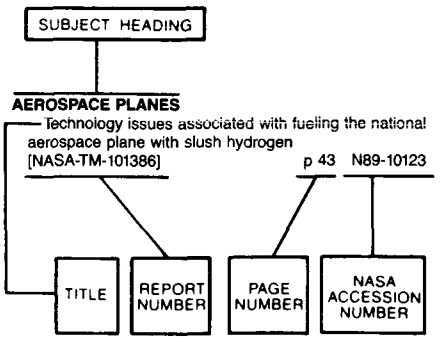

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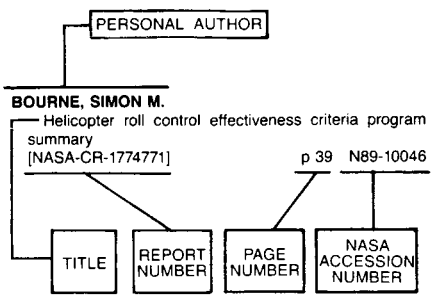

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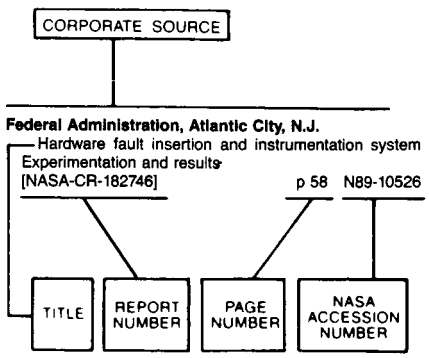

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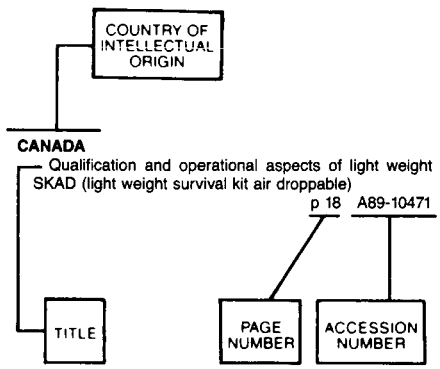

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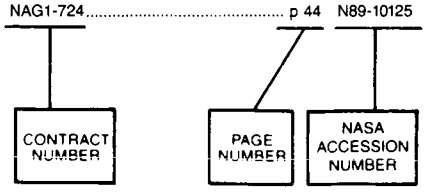

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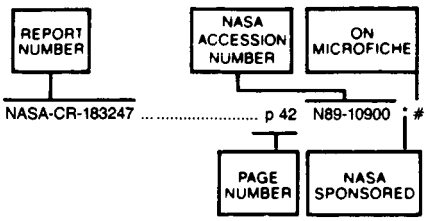

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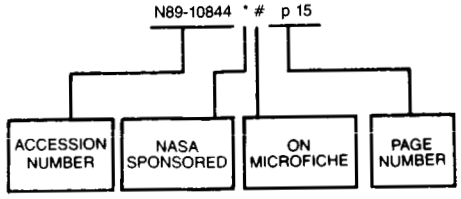

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